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Chicago: DWIGHT H. EARLY
100 North LaSalle St.
Telephone: Central 4158

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Engineering Farm Truck Use

MOTOR trucks have been well designed and well built from an automotive standpoint. They will do a hauling job wherever there is the semblance of a road or other reasonably flat surface which will provide traction. Their development for farm use has required little or no agricultural engineering attention to their design. Even the body types developed for various commercial hauling jobs have proven satisfactory for farm hauling of similar materials.

There are agricultural engineering problems and opportunities, however, in connection with the selection, utilization, maintenance, and replacement of farm trucks. Any farmer can drive a truck, but getting the most out of it as a unit of farm operating equipment is a matter of applying principles of investment, fuel, material, and labor economy. In this the truck must be considered in relation to other farm equipment and to the whole production program and operating setup of the farm as a producing unit. It is an agricultural engineering job to work out and state the principles, and establish application data which can readily be applied to show what motor truck investment, capacity, and use methods may prove most economical on any particular farm.

AGRICULTURAL ENGINEERING

VOL 21, NO 7 EDITORIALS JULY 1940

Engineering and Leadership

WE commend especially to the thoughtful reading of agricultural engineers who are young in years and spirit, the address on "Training for Aggressive Leadership," by K. J. T. Ekblaw, published in this issue.

Engineering and leadership are two different things. Many engineers are not leaders. Many leaders are not engineers. But there is a good reason why it would be desirable if the two were combined in more of the same individuals. The discipline of engineering training and work helps develop, in most men who become engineers, qualities of intellectual honesty and personal integrity which help steer leaders in the right direction. By "right direction" we mean direction which will give most satisfaction in the long run to the leaders as well as to those who are led. Do you have to go beyond your own circle of personal acquaintances to note cases of men actively leading great or small affairs in directions which you would question? Probably not, but if so, the front page of the daily paper will furnish examples.

The affairs of men need, not only more leadership, but a higher character of leadership. And as Mr. Ekblaw points out, leadership is the result of a combination of personal qualities inherent in most people to greater or less degree, subject to development, but which few individuals develop in themselves to their fullest capacity. Engineers can never furnish all of the leadership which will develop in this world, but what they do furnish can be of high quality, and that seems a good reason why engineers individually, and as a profession, should make a concerted attempt to develop and exercise their capacities for leadership.

It also seems logical that engineers, being concerned with the development, conservation, and use of human and natural resources, should practice what they preach and begin at home with the fullest and highest development of the resources of their individual minds and bodies.

Agricultural Factors in National Defense

TWO general ways in which agricultural engineers can aid the national defense program evolved from discussion of the subject at the recent annual meeting of the Society. Our relation to agricultural production phases of a defense program is obvious. Increased economic and mechanical aspects of modern defense further suggest that training and experience has qualified many agricultural engineers for important work in military phases of the defense program and in nonagricultural as well as agricultural phases of the national economic foundation for defense. The defense program puts a premium on engineering ability and accomplishment in effective use of men, materials, energy, and mechanical equipment. There is perhaps a danger that nonagricultural phases of defense will absorb agricultural engineers to the extent that their possible contribution to its agricultural phases will be weakened.

Agricultural problems of national defense involve continued production of staple commodities and new or increased domestic production of important commodities or of substitutes for commodities previously imported.

From a defense standpoint we are blessed with substantial stores of staple farm commodities, with widespread favorable climate, soil, and farm population, and with existing knowledge and facilities for substantially increasing production per acre or per man-hour. But preparation for defense is a matter of preparation to meet possible contingencies.

So far as staple farm products are concerned, plans need to be made and ready to be put into effect on occasion, to adapt production to new requirements and new conditions which might develop. Some commodities might be needed in greater and some in smaller amounts.

Defense with a large army and navy suggests plans for continued farm production with reduced manpower.

Defense involving actual military operations in this country suggests plans for maintaining farm production without benefit of some areas now in production.

Defense against "fifth column" activities suggests plans for further decentralization of farm product storage.

Any substantial defense suggests the possibility that certain strategic materials now used in making farm equipment may be exhausted or less readily available for such use. Planning for redesign and use of substitute materials may be in order.

Additional problems are involved in maintaining supplies of organic materials which we have, up to now, imported in large quantities. Production in this country might be started or increased quite rapidly in the case of sugars, starches, proteins, vegetable oils, fibers, and certain sources of important pharmaceuticals or other organic compounds. And many of these allow considerable opportunity for substitution and for chemical changes in processing to meet requirements. Relative to some other important commodities, such as rubber and coffee, our position is not so secure, and possibilities of early domestic production are much less promising.

Defense considerations suggest that the whole subject of organic material requirements, present sources, and possibilities, means, and economy of domestic production be analyzed for opportunities to improve our position by agricultural engineering attention to the nature, variety, methods, and economy of American farm production.

And, however great the immediate urgency of defense measures, there is also occasion to look and plan ahead for a sound agriculture when the immediate defense emergency has passed—for realization by farmers as well as the rest of the nation, of the freedom and opportunity our present defense program seeks to preserve.

Environment for Production

SINCE publication of our editorial on "Factors in Farming Effectively,"[1] we have been called, and justifiably, on our implication therein that farm operations "provide environment" for the growth of crops and livestock. More explicit language is warranted.

Crops and livestock live in environment provided, not by man, but by the very nature of things. The idea we

[1] AGRICULTURAL ENGINEERING, Vol. 21, No. 6 (June 1940).

meant to convey was that operations, manipulations, and controls provide, or result in, specific environmental conditions other than those which would result by letting nature take its course. In other words, the farmer modifies crop root environment by tillage, poultry environment by housing, and marketable product environment by pasteurization, refrigeration, ventilation, and similar means.

The point of our argument was that the agricultural engineering work of improving mechanical and electrical devices, structures, controls, manipulations, and operating methods for modifying environment for effective farm production, could proceed more soundly and rapidly if it could be based on more accurate information as to biological response to specific conditions of environment.

Work for Engineers

SHOULD agricultural engineers take an active interest in economic and social matters, and if so, how far should they go in these fields? Or, restating the question, could agricultural engineers individually and collectively do more effective work by supplementing their technology with increased understanding of certain phases of economic and social science?

Other branches of engineering face similar questions, and opinion ranges between wide extremes. We do not pretend to have the final answer, but believe that free discussion may help to clarify the issue.

The whole question arises from criticism of engineers and engineering work as an apparent cause of undesirable economic and social conditions, of some individual engineers on the ground that they are not broad enough to do as effective work as their employers or prospective employers would like to have them do, and from the desire of many engineers to work more effectively. It has been emphasized by the relative depression of the 'thirties, following the machine-made prosperity of the 'twenties. Farm mechanization has come in for its share of adverse opinion.

Those who believe that engineers should tend strictly to their technical knitting point with considerable logic to the fact that this technical field is already larger than any one individual can fully master in all of its phases and details; that most engineering work is sound and valuable, and therefore can survive unfounded criticism; that economics and sociology are young sciences with little background of quantitative knowledge applicable in engineering methods of thought and work; and that, as indicated by an old adage, a little learning in these fields may be dangerous, as it clearly is in engineering.

On the other hand, engineers are human beings and necessarily interested and personally involved in economic and social relationships. Some minimum understanding of these matters seems indicated as a prerequisite to effective life and work. The question is, how much understanding in these fields, and how much effort to acquire it, can be of more value to engineers than the additional finesse which might be developed by applying the same time, study, and thought to engineering technology?

Opportunity for engineers to work depends on someone seeing specific opportunities for engineering technology to serve economic or social purposes, and providing the required financial support. These people with the power and will to initiate engineering work may be engineers who are more than technologists, having an appreciation of human needs and of various ways in which technology might be applied to help satisfy those needs. Or without being engineers, they may be business men, politicians, or citizens in other walks of life who have some appreciation of the physical results which can be brought about by engineering technology, and used to human advantage. Obviously persons who are uninformed, indifferent, skeptical, or directly opposed to the changes in the agencies and ways of living and of earning a living, which can be brought about by engineering technology, furnish little direct employment for engineers.

In a democracy public opinion influences engineering opportunity still more broadly from the standpoints of employment in public service, legislation, and acceptance and use of engineered commercial products and services.

Now, if engineers can be sure that they have and will continue to enjoy all the opportunity and support they can use to advantage, by reason of favorable public opinion, of work being thrust upon them, and of appreciative employers paying fairly for technical achievement, there might be little need of engineers learning anything of economic and social considerations. They might perform great and satisfying service as appreciated minions of worthy masters.

But if engineers are unemployed or poorly employed because there is a shortage of men with the understanding, vision, and aggressiveness needed to put engineers and engineering technology to work serving specific economic and social purposes; if the potential value of engineering needs to be sold and kept sold to a changing and confused but powerful public facing a complex world; if engineers are underpaid because the difficulties and values of their work are not fully appreciated; if engineers are to be leaders and effective cooperators, getting engineering technology into action whenever, wherever, and however it can serve legitimate human interests, then it seems in order for engineers to show an intelligent interest in economic and social considerations.

This does not mean that engineers need to learn all the ins and outs of banking, the wholesale grocery business, criminology, social settlement work, and a thousand other phases of our economic and social life. It does not mean that they should become supermen. It does mean that they should know something of the place and influence of their work in the cause and effect relationships of economic and social phenomena.

It means that they should be able to look at life as it is lived, and see the need and opportunity for new machines, improved structures, and simplified operations. It means that they should be able to understand and to explain to their neighbors the influence of engineering developments on production capacity, employment, wages, living and working conditions, education, and other human values.

It means that agricultural engineers need to think in terms of farm working and living conditions, of making the farm attractive to the highest type of farm youth, and of helping farmers increase their capacity to render economic service, in addition to thinking in terms of man-hours and horsepower-hours per operation, per acre, or per bushel. It means relating the technically possible to the economically feasible and the socially desirable. It means thinking in terms of helping farmers move a step ahead of where they are. It means counteracting a lot of misinformation, misunderstanding, and plain hokum about the good old days, the cost of farm equipment, the price of farm products, and the danger of modernization reducing farmers to peonage. It means that agricultural engineers are the logical persons to apply engineering technology to practical farm problems.

Training for Aggressive Leadership

By K. J. T. Ekblaw
FELLOW A.S.A.E.

THE reason I am appearing before you at this time is because it is customary for the president of the Society to address its annual meeting. What I shall say is something that is very much in my heart and mind at this time, something that has come to have, I believe, importance to our Society as a whole and to each of its individual members.

If there is anything that the world needs, it is strong, inspiring, aggressive leadership, and that is what I am going to talk about.

Let us view the prospects and opportunities for leadership that normally exist here in our own country. When we study our national and our agricultural situation, and get down to a real appreciation of what is happening, the great need for leadership, and for training in leadership, becomes clear.

K. J. T. EKBLAW

In spite of the fact that there have always been manifold and serious problems concerning it, farm life, as developed in the typical American way, became one of the most important factors in the stability of the social and industrial life of the country. A condition of relative smoothness in operation and the production of consistently satisfactory results obtained for over a century of rather steady development. In recent years this condition has changed rather materially. Following the World War, agriculture descended into a depression from which it has, as yet, not recovered. Something happened to American farming, which rather suddenly transformed it from a profitable, self-supporting productive economic system into a confused, dependent, profitless industry which is desperately trying to work out some sort of a satisfactory salvation in relation to other economic groups, and finding it an extremely difficult task. Just what the causes were of this dismaying transformation is a matter of divergence of opinion, and it is not my purpose to recite them here or to argue their relative weight. We know that agriculture was thrown into serious unbalance by the establishment of new power systems, by tremendous changes in crop production, by worldwide readjustments of markets, by new conceptions of what constitutes correct relationships of capital and labor, and by other similar factors. All these things seemed to come to a climax in the early part of the present century. Astounding demands came upon all industries, and almost superhuman efforts have been made to meet them. Agriculture suffered perhaps most of all; and the difficulties to be overcome in meeting the demands that have come upon it appear to be almost insurmountable.

Tremendous undertakings in the readjustment of agriculture to the new regime are under way. Agriculture may have been asleep; it may not have been aware of the changes that were quietly but effectively being accomplished in other industries. Certainly now it is awake, wide awake, and things are beginning to happen. Not only is agriculture itself thoroughly awake, but the whole nation has come to a somewhat late realization that it is upon agriculture more than anything else that its economic prosperity depends.

It is well indicated that science is destined to lead the way in this rehabilitation of the agriculture of our country — science, as expressed in physics, in biology, in chemistry, all of which are part and parcel of engineering. Engineering in agriculture is the answer—and engineering in agriculture means *agricultural engineering*!

In this very sketchy painting of the picture that lies before us, I am sure you can see the things that lead me to the conclusion that one of our greatest needs today is leadership—*strong, intelligent, aggressive leadership*. Oh, the demand for leaders is upon us right now! How I hope that our Society and our individual members will recognize and appreciate it! How I hope that our agricultural engineers may see the opportunity, and seize it, to the great advantage of themselves and of our country!

DEVELOPING QUALITIES OF LEADERSHIP

Now, the one main point that I want to make is this: *Leadership can be developed.*

It is probably true that the qualities that make for leadership are not possessed by all individuals to the same degree; but I am sure that every one possesses these qualities to *some* degree. Therefore, since leadership itself is such a valuable and desirable thing, it is each one's personal duty and obligation to cultivate and develop what share he possesses of these qualities to the fullest possible degree. To that degree, he can become a real leader.

You have seen, as I have, many an individual fall far short of the attainments which were clearly indicated to be possible for him. Many may have been the reasons for such failure but all of them could have been cancelled had someone convincingly brought him to a realization that he had within himself the power to rise to far greater heights.

Likewise, many individuals, with possibly remarkably great potentialities as leaders, have bogged down into the ruts of commonplace routine, simply because they did not appreciate their own capabilities for inspiring their fellows, and no one saw fit to give them the right kind of a push in the right direction at the right time.

Perhaps you have sometime wondered just what constitutes leadership. It is a quality that is rather hard to define in a word or two. It is really a combination of qualities: Knowledge is a fundamental constituent; vitality, vigorous vitality, is another; personality is another; the

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Address of the President of the American Society of Agricultural Engineers before the 33d annual meeting of the Society at State College, Pa., June 17, 1940. Mr. Ekblaw is agricultural engineer, American Zinc Institute, and vice-president, Western Advertising Agency.

ability to make quick and correct decisions is important; a certain amount of determination and pertinacity enters into it; as does the ability to take defeat and not be conquered by it, but to come back into the fray with new vigor and strike harder than before.

These are some of the things that constitute leadership; and I maintain that every one of these qualities are qualities that can actually be cultivated and developed.

Let us face this problem as it concerns agricultural engineers particularly. What are some specific things that agricultural engineers can do to become real leaders?

PERSONALITY FOR LEADERSHIP

Perhaps personality is a good thing to start to work with. Ask yourself if you have ever given a thought to developing your own personality. Have you just gone along complacently believing that every one likes you just as you are? Don't you think that you could do something to improve yourself so that your relations with your fellows would be pleasanter, happier, more agreeable? Don't you think that if you really tried, you could talk more intelligently about practical subjects, that your language and your conversation could be made better and more understandable, that you could act a little more courteously, that you could be more considerate of the other fellow, that you could be more unselfish in your relationships with your associates—*if you really tried?* I am sure that every one of us could.

If I so desired, I could cite a hundred instances in which the personalities of individuals had changed, for better or worse, in a relatively short time. So could you. It only helps to prove my point that personality, one of the essentials of leadership, can be cultivated and developed. So, when we are about it, let us make sure that the development proceeds in the right direction, and that we improve personality rather than spoil it.

SELECTIVE GROWTH IN KNOWLEDGE

Another next thing that an agricultural engineer should consider in his progress toward leadership is knowledge. Presumably he has a good supply of it, but is it of the right kind? It is not my intention to lay out an agricultural engineering curriculum to define the kind of knowledge an agricultural engineer must have, but certainly if he is going to be a leader in the agricultural engineering field, he must have more than a smattering of the subject. You simply can't have too much knowledge, but don't try to get it all, all at once. Concise, accurate, useful knowledge can be acquired by anyone who will apply himself painstakingly. In our field, as in all others, we suffer from the incompetence of those who have only a slight knowledge of the work they are doing. The quantity of knowledge which an individual can absorb depends upon his mental capacity, but if he aspires to real leadership, what knowledge he does acquire must be useful and factual. An agricultural engineer must necessarily cover two great fields, agriculture and engineering, and the amount of scientific knowledge that has been developed in these fields is so great that only an incredible genius could acquire it all. Therefore, the greater need to make sure that what we do select to learn is really useful and true.

EXERCISING CHOICE IN EXPERIENCE

After knowledge comes experience. Here our choice is perhaps narrowed. Often our experience is controlled by circumstance, but again, if our determination is sufficiently strong, we can choose the avenues in which we progress and can thus largely determine the character of our experience. Very few individuals seem to have the ability to select a certain line of endeavor early in life and follow it through consistently. Perhaps it is well that this is so. But certainly, by the time we are beginning the acquisition of what we call "professional experience," we ought to know pretty well what we want; and if we want to become recognized for leadership in some particular field, we must concentrate in that field. You have seen, just as I have, many a career that has been ruined because an individual refused to concentrate: He moved about from job to job like a will-o-the-wisp, led by the flimsiest and most meager influences. It takes courage and determination to acquire the right kind of experience, the kind that will contribute substantially to real leadership, but, again, it is a thing within our control.

BREADTH OF KNOWLEDGE AND EXPERIENCE

But it will not do for a leader to be narrow in his knowledge and experience. He must be informed on many general subjects; he cannot stay exclusively within his own field; he must venture abroad and acquire some knowledge in other fields into which he may possibly have to continue his leadership. He may possess a natural talent for financial affairs; he may possess managerial ability; he may be led into the field of practical politics; he may have inherent within him the qualities of administratorship. These opportunities for exercising special talents generally appear coincidently with the development of leadership, so it behooves the individual to be prepared for such eventualities by fitting himself with a supply of practical knowledge on general subjects. This can readily be acquired by systematically following a set plan of selected reading, by conversing with well-informed specialists in various subjects, and by collating and correlating such information as is thus obtained.

One of the surest indications that a man is a real leader is the breadth and accuracy of his general knowledge. It proves that he has trained himself to think straight, to develop his own ideas, and to express them clearly, simply, and forcefully.

On the other hand, the man who lets others do his thinking for him, who is too lazy mentally to do the necessary winnowing of the wheat from the chaff, will never be a leader. Too often we are swayed by the specious arguments of others. We must build up our own reserves of general knowledge so that we can express sensible opinions, if we are to gain general recognition as leaders.

RESPONSIBILITIES OF EDUCATIONAL INSTITUTIONS

So much for that phase of the subject. I could continue along the same line, but now I want to shift my attack from the responsibility of the individual to that of the institution in which he gets his training. However, I do not mean to be presumptuous when I make certain suggestions which I am confident will help the individual acquire the qualities of leadership.

Narrowness of development is a fault that can be blamed upon both the educational institution at which an agricultural engineer gets his technical training and the organization in which he gets his professional experience. What to do to correct it is far beyond the scope of this talk, and, indeed, far beyond my ability to suggest. I do think, however, that greater effort should be made both by educational and by industrial organizations to broaden the basis of the schedule of study and labor, so that the coming agricultural engineer, as student and as apprentice, will have the chance to become more than a mere technician and possibly a very mediocre, half-baked one at that.

At the risk of being called old-fashioned and reactionary, and of being challenged by *(Continued on page 263)*

The National Defense, Agricultural Engineering, and Farm Chemurgy

By Wheeler McMillen

A CHARACTERISTIC of the engineer in agriculture, as in other branches of the engineering profession, is that he carefully defines and limits his problem before laying out a plan for its solution.

The United States is faced with the problem of insuring the future of a free people. Like most problems, it constitutes an opportunity. In the imperative duty of national military defense, the country today has an extraordinary opportunity to strengthen its economy, to revitalize the spirit of its citizenship, and to perpetuate on this hemisphere the American heritage of Freedom.

In meeting this opportunity, agricultural engineering and chemurgy each has a share.

The situation as of today demands a cold analysis, an analysis that will determine the fundamentals of the problem. What will defense of our nation require next year, and in the years to come? What facts will be changed, and what facts will remain? What ideals and areas and conditions are to be defended?

Clearly enough the will of the American people is that the strength of the nation be organized to defend American territory, American ideals, and American conditions of freedom and individual opportunity. With such a will so definitely manifest, in a world where none can predict the details of tomorrow, the time is here when this country must be ready to take the aggressive, not for aggrandizement, but for the preservation of Freedom.

AREA OF DEFENSE IMPORTANT TO THE UNITED STATES

This is not a time to sit back and wait for bad news. Rather it is a time to guarantee good news for all the future generations of America.

The United States does not need more territory to enlarge or enrich its living room. But, if the American ideal of Freedom is to be insured against outward attack, the nation must not fear strong measures. If, at any moment in future months, there appears the slightest authentic likelihood that tyrants of the Old World contemplate approach to the Western Hemisphere, the United States should be ready and able to control and hold every spot of military, naval, or aviation base value between the north pole and the equator in the western world. If, in order to have such protection, it is necessary to exercise authority over the people and lands involved, we should not shrink from that possibility.

This is the geographical area of our defense. This area can be defended against any possible coalition of forces, if the American people so determine. No land in North America that is ably and loyally defended can be conquered, unless it can be occupied. No power or coalition of the Old World can ever hope to land in this area the millions of men and the millions of tons of metal that would be necessary for occupation. The oceans between us and the old continents, and oceans and the terrain between us and lower South America, are far more powerful barricades than the imaginary lines, however fortified, that separate the small countries of Europe.

The immediate task of the nation is to provide whatever military, naval, and air forces are necessary to insure such protection. The likelihood of an actual need for protection on such a scale may be very slight, but, just as one carries automobile liability insurance no matter how carefully he drives, the insurance of adequate defense is indispensable in a world where anything can happen and sometimes does.

DEFENSE FOR PEACE TO PRESERVE DEMOCRACY

No less immediate in urgency is the internal defense of Freedom under representative government. Already we hear the voices of distinguished leaders in education, in journalism, in business, and in government urging that the United States declare war at once on Germany. Beating the drums of emotion and fanning the fires of hatred, they believe that Europe's affairs are our affairs, and that what they call democracy can be preserved by our participation in this latest outbreak of the feuds that have devastated Europe and stifled liberty there for centuries. They forget that with a declaration of war the United States itself of necessity must enter into the conditions of dictatorship for the duration of a war of long years or decades, to be followed if ever by a peace that may not see representative government restored in our lifetimes. I for one prefer the course of building a defense to make war impossible in North America.

The construction of a sound and complete defense calls again for aggressive action. Far more than the equipment of armament is to be considered. The most important elements of defense are unity in Americanism and economic superiority.

The lag in economic development of the nation has imperiled our unity as well as our defensive strength.

NATIONAL ECONOMIC STRENGTH IMPORTANT TO DEFENSE

For a dozen years, many who have held the high pulpits of public office, and who through the press and radio have commanded the eyes and ears of the public, have pointed a contemptuous finger at those of us who dared to proclaim our belief that the resources of the United States should be developed in preference to those of foreign countries. They have sought to damn us as "isolationists." They have curled their lips and called us "nationalists." They have insisted that American farmers must sacrifice the home markets to foreigners in the interests of international trade. They have openly fought our efforts to stimulate research in order that the magnificent possibilities of our agriculture might be more fully realized. They have declared that their policies were the route to interna-

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An address before the annual meeting of the American Society of Agricultural Engineers at Pennsylvania State College, State College, Pa., June 19, 1940. The author is editor-in-chief of Farm Journal and Farmer's Wife, and president of the National Farm Chemurgic Council.

tional peace! Many of them are the same persons who today are clamoring for intervention in the shambles of Europe where there is no peace, and they are as wrong today as they were yesterday.

Now that the defense of their nation must be strengthened, I hope some of them will be decent enough to hang their heads in honest shame. They must know that the military strength of a nation in the last analysis has to depend upon its ability to command, from within its own borders, the materials necessary to sustain not only the armed forces but the whole civilian economy of the country. The United States has failed to fortify itself internally as woefully as it has failed to provide its armed defenses.

Five years ago, in July 1935, at the request of the chairman of a special committee on research appointed by the Secretary of Agriculture, I prepared a brief on agricultural research. In it were the following words:

> "The national defense must always be a foremost consideration of statesmen. To this end that the peace and safety of the United States shall be assured, we take for granted the necessity for maintenance of an army with sufficient subsidiary means for military preparation, of a navy prepared to defend our shores and ships—both with their various branches for air, land, and water, and their supporting agencies.
>
> "Preparation for provision of adequate supplies of all kinds for these fighting agencies, from our own national sources within our own national borders, is looked upon as an axiomatic necessity of national defense. Such supplies include not only munitions, food, clothing, medical requirements, and transport for the fighting forces, but all commodities necessary for the support and morale of the non-combatant population of the country.
>
> "From the standpoint of national defense, the clear objective of research should be to make provision for the production, at some cost, from some domestic source, of every item that it is anticipated may ever be required for the use of our defensive forces; and, further, of every item of domestic need that might be shut off by the incidence of foreign wars in which this country may not be engaged.
>
> "Department of Agriculture research projects which clearly contribute to these ends should, therefore, be worthy of consideration by the Congress."

DEFENSE OF THE AMERICAN STANDARD OF LIVING

Alongside the defense need for ample domestic supplies of raw materials has been the imperious need of our farmers for additional profitable enterprise and of our workers for additional employment. While the cotton markets of the South have been fading away, little has been done to enable southern farmers to replace cotton with new crops. This inactivity has been in the face of annual importations of two billion pounds of oils and fats, some of which certainly could be produced on cotton lands. With an agricultural area in the United States that embraces almost every possible condition of soil, altitude, temperature, and humidity, we still send overseas for essential supplies of jute, hemp, flax, long staple cotton, coarse wool, and other fibers.

There is another angle in the national defense that certainly will have to be faced whatever the outcome of current struggles. Whether the eventual victor in Europe is Hitler or the British, whether the United States enters the war or not, whether Hitler threatens the western hemisphere or not, we in this country are going to have to establish defenses for the American standard of living.

The instrument required for this purpose is the unleashed production of the materials and goods which Americans consume. Production creates earning power, and earning power is the basis of the standard of living. Standards of living can not be advanced without a dynamic production machine ever moving on enlarging paths. A shrunken production will either produce or perpetuate depression. That is why depressions inevitably follow wars, and why more depression will follow the present war with a painful shock to American standards unless intelligent national, industrial, and agricultural statesmanship intervenes to set in motion additional forms of production.

Those of us who have urged the farm chemurgic program have believed that by establishing new crops to supply the materials now needed and consumed in America, by developing new uses for farm products, by finding markets for agricultural wastes, the profitable output of agriculture could be increased. You in the fields of agricultural engineering have worked to reduce the costs of production, and to improve not only productive efficiency but the ability of producers to enjoy the fruits of their work. Thus chemurgy and agricultural engineering operate hand in hand for the military and civilian defense of our country, and for the defense of our standards of living.

ECONOMIC DISASTER IN AMERICA CAN BE AVOIDED

Those who predict economic disaster for the United States as a certain consequence of possibilities abroad, are walking in the sleep of their own ignorance. Only six per cent of the national income of the United States derives from foreign trade. Five times that amount of activity can be generated by our agriculture alone, if the land is enabled to produce fully for American markets and encouraged to create the new earning power of which it is capable. This country needs to wake up to the job of implementing its own consuming power. It needs columnists and commentators and public leaders who know about science as well as international politics.

No one can set an upper limit upon the possible production of wealth by farmers. In the first place, the raw materials of agriculture are mainly atmosphere and rain, of which supplies are ample. The plant geneticist, with his ability to develop crops to industrial specifications, is opening wide new fields. The organic chemist, with his ability to transform plant substance into wholly new forms of material for human use, is opening broad new markets. The flora of the world should all be re-examined for the geneticist and chemist. We can anticipate, if we can not foresee, the eventual use of farm-grown raw materials for commodities as new to our standard of living and as much a part of it as the motor car and radio, unknown and undreamed of a few years ago, are now.

RESEARCH AND NATIONAL OBJECTIVES

Such developments can only follow the kinds of research for which chemurgy cries. They can follow only such applications of agricultural engineering as your profession will provide for devising sound, economical, and reliable procedures in production and handling. Chemurgy's progress depends quite as much upon the engineer's work toward economical production and handling as upon the research scientist's basic studies.

Here in America already, because of the great productivity of our people under Freedom and because of Freedom, we have erected a nation long the envy of all the Old World. We shall defend it to the uttermost limit against invasion from without or destruction from within. Nor shall we be satisfied to defend it. Our obligation and our determination shall be to advance this nation in the paths of power, in the ways of peace, and toward higher standards of plenty.

The Economics of Farm Machinery

By Dr. John Lee Coulter

BECAUSE you who constitute my audience today are yourselves students of the various engineering problems of agriculture, perhaps it is unnecessary for me to even remind you that during untold thousands of years members of the human race subsisted either by hunting and fishing, or later by grazing their flocks and herds of domesticated animals, thus utilizing the natural resources of the areas in which they lived. Let me repeat that this condition continued over many thousands of years. During additional hundreds of years the people gradually developed the use of primitive tools and implements, operated wholly or almost wholly by the physical labor of the people themselves. Farm machinery is so modern that, in large measure, it dates back only to the founding and settlement of our own country.

Even today literally untold thousands of people continue to utilize the natural resources in the areas in which they live with the aid only of the same primitive tools and implements, and only now are commencing to introduce the use of more modern farm machinery. I said untold thousands of people; without exaggeration I might as well have said untold millions; indeed, it would not be an exaggeration to say that a billion human beings continue the use of the most primitive implements, tools, and machines, although during recent centuries domesticated animals have been used to some extent to supplement human labor in the operation of primitive equipment. Horses, mules, and cattle especially have added their physical weight to the efforts of human beings so that, in addition to supplying dairy products, meats, hides and skins, wool, hair, etc., or animals for the chase and for war, they have become the so-called beasts of burden.

During these long periods and over these vast areas, involving tremendous numbers of people, it required almost the whole time of practically all of the people to provide merely for the bare subsistence of the population. When not engaged in actual production, all members of the family joined in preparing the hides and skins for use, or in carding, spinning, and weaving fibers, or in otherwise preparing or preserving the products of the growing season for later use. To state it another way, relatively few could be spared to pursue the arts, sciences, or other pursuits of life. That is to say, *modern civilization awaited the development of farm machinery to relieve important elements in the population from the primitive tasks of producing the requirements of subsistence, and one might almost say that all modern progress dates from the work of the agricultural engineer.* I am therefore delighted to come before you to compliment you and those who preceded you in the tremendously important task of reducing the human burden necessary in producing the basic materials necessary for the maintenance of human society. You and those who preceded you in this great task deserve the highest degree of praise from mankind.

While much was accomplished in western Europe and during our own colonial days, the real foundation for the great development of agricultural machinery was laid during the first one hundred years of our national life and the scene was in the United States of America. I refer to the period extending from approximately 1775 to 1875. Even during our own colonial days almost the entire population found it necessary to devote its time to the production of the basic materials of life, the clearing and breaking of wild land, and the building of necessary shelter. In other words, so-called city population was limited to an extremely small number at the beginning of our national existence. Thus, in 1790 there were only six places in the United States with a population of 8,000 inhabitants or more, and

An address before the annual meeting of the American Society of Agricultural Engineers at State College, Pa., June 17, 1940. The author is a consulting economist.

Development of science, the professions, the arts, widespread education and literacy, natural resources, manufacturing, transportation, commerce, and the comforts and conveniences of modern life —from which few choose to turn back to more primitive days and ways—has largely been made possible by the increased efficiency of farming, and the resulting release of three-fourths of the population from the necessity of producing its food and clothing, to utilize its time and energies in these other activities

only 3.3 per cent of the total population lived in these cities. At the present time more than 50 per cent of our people live in places of 8,000 inhabitants or more.

During the 100-year base period referred to approximately one-fourth of the people of this country were released from farm labor and permitted to turn their attention to building up the other great natural resources of the nation. In other words, soon after 1875, 25 per cent of the total population lived in places of 8,000 inhabitants or more. But this is not a true indication of the extent to which agricultural machinery had released labor from farm operations. At least another 25 per cent of the total population was also engaged in activities other than farming by 1875. They were engaged in mining and forestry, in canal, road, and railroad building, and in the organization and development of all other forms of human effort. In other words, it may safely be said that during this base period, fully one-half of all farm labor had been released for other than the production of basic necessities on the farm. This is the same as saying that the development of tools, implements, and machines had doubled the capacity of those on the farms to produce the requirements of life. Brief statistics may be cited as evidence. The number of farms in the United States reached 4,000,000 in the period between 1875 and 1880, and the population of the United States reached 50,000,000 during the same period. In other words, each farm provided the requirements for food, clothing, boots and shoes, and other leather products and all of the other necessities of life for an average of 12.5 people. Since the population per farm probably did not exceed 6.25, it is evident that one-half of the people, on the farms, supplied requirements for the entire population, in addition to exports sufficient to purchase in foreign markets all of those things not produced in our own country and needed by our people to further develop modern America.

TYPES OF FARM EQUIPMENT RELEASING LABOR FOR OTHER WORK

First came the implements and machines for the preparation of the soil and making the seedbed, especially the plow and harrow. May I remind you that, at the time of the founding of this republic, a smithy and a farmer, attempting to plow a piece of sod with an iron plowshare, were mobbed by a community fearful lest, on the one hand, the contraption would poison the soil and this poison would spread across the countryside, and on the other hand, the opportunity for labor would be destroyed and great numbers of people would be left unemployed.

Second in importance came the planting of grain and seeds. Prior to that time all of this had been done literally by scattering the grain and seed by hand of the operator as he marched up and down the field.

Third in the series was the development of implements and machines for the cultivation of crops. True, the small grains which were broadcast, and the hay and pasture grasses, called for no further cultivation than the harrow or the dragging of piles of brush over the land to level it and cover the seed. But there was corn and other crops which called for cultivation, and human labor could only be displaced when machines were developed to supplement the shovel, spade, hoe, and hand rake. Disks, spring-tooth harrows, and a multitude of horse-drawn and power-drawn special cultivators are the modern developments.

Next we come to the harvesting of the crop, and I need mention only the mower, the reaper, the harvester, and machinery for gathering the corn, although scores of other special machines were gradually introduced.

And finally, reference must be made to the threshing machine and all of the other modern devices to separate cereals and other products from the mature plants.

A volume might easily be written on each of these five major divisions into which I have grouped the development of modern farm machinery. And I have not even mentioned the scores of special types of equipment for the storing and preservation of the products or for such purposes as grinding feed, milking cows, and a host of other jobs.

Suffice it to say here that, from the standpoint of the economics of farm machinery, each step forward in each of these fields made possible larger production and the releasing of new large numbers of people from the production of raw materials, so that their time might be available to engage in other phases of national development. I cannot too much emphasize the undeniable fact that a large part of our magnificent growth has been made possible by these developments of agricultural tools, implements, and machines.

RECENT PROGRESS IN FARM OPERATING EFFICIENCY

From what I have already said, it might be concluded by the uninformed that substantially all of the great improvements were made prior to 50 or 60 years ago. I must, therefore, devote a few moments to passing reference to more recent accomplishments. But the recent period must be divided into two parts, the 25 years preceding the World War and the 25 years since 1915.

During these last two generations, substantially as much has been accomplished from the standpoint of economy of agricultural production in the United States as during the previous historical period.

Whereas, in the period 1875-80, substantially one-half of the total population of the United States lived on farms and were largely engaged in the production of the requirements of this country, with only sufficient for export to pay for our own requirements from foreign sources, now only one-fourth of our total population lives on the farms of the nation. In other words, 75 per cent of the total population are free from farm work to carry forward the other activities in our great national economic progress. Thus, from the standpoint of efficiency and unit production, agricultural output per man unit has probably at least doubled during this period. This is the result, not primarily of increased yields nor of new products, but is the result largely of greater efficiency and this, in turn, is largely the result of the development of tools, implements, and machines for farm use. We still grow the small grains, wheat, oats, barley, buckwheat, and rye, not very differently than 100 years ago, although in different areas. We still grow the cultivated crops like corn, cotton, and tobacco, likewise in very much the same way, although again in different areas. The marvelous change that has come about has been the adaptation of tools, implements, and machines to the use of man which, in turn, has now released 75 per cent of the total for other activities.

Let me put it just one additional way. At the present time our population considerably exceeds 130 million people, while our farm population is less than 32,500,000, or 25 per cent of the total. While it is true that farm operators employ two million or more laborers during the year to aid in the carrying on of farm work, it is equally true that more than two million farm operators, on the average, secure 100 days of labor away from the home farm. Most of this is nonfarm labor, so that these items substantially cancel each other.

Consider human existence as a prequisite to the development and realization of some higher human values. Then the production of food and other necessities of human life become biological maintenance functions. From this viewpoint, agricultural engineers have justified their existence by their contributions to the dispatch with which human maintenance problems can be and are cleared from the path of progress toward higher human objectives. But agriculture is not limited to the production of necessities; other material and energy factors influence the direction of human aspirations and effort; and farmers have lives to live. Agricultural engineering is justified wherever and however its techniques can aid the realization of higher human values

From this brief statement, it must be clear that agricultural efficiency from the standpoint of production has increased roughly 100 per cent in a period of 50 or 60 years, since we are still exporting large amounts of products to provide funds with which to purchase products desired from other parts of the world.

Agriculturally speaking, the historical period, 1895-1915, was not only one of tremendous expansion in farming, but one of magnificent improvements. These improvements may largely be traced to two things: (1) better farm equipment was better adapted to the special uses for which it was made; and (2) steadily declining prices for most of the important farm implements and machines at a time when prices of farm products were generally advancing, land values were increasing, and farmers in general were improving their standards of living. I noted first the improvements and greater adaptability of farm machines to special farm needs. I need go no farther than to say that this applied not only to plows, harrows, and cultivators, but to seeders, drills, and planters, and likewise to mowers and rakes, harvesters and threshers alike.

DECLINES IN FARM EQUIPMENT PRICES FROM 1880 TO 1915

I must make more specific reference to the steady decline in prices of most important farm implements and machines during the period in question, the period from about 1880 to about 1915. First of all, it is to be noted that the number of farms increased more than 50 per cent during this period (from 4,008,907 in 1880 to 6,361,502 in 1910). This gave a tremendous impetus to the farm machinery manufacturers. Standardization approaching perfection was accomplished in many cases during these years. This made possible great interchangeability of parts in many cases. This, in turn, made possible mass production, which was built upon technical and scientific improvements. Efficient management, added to these other features made possible constantly decreasing price levels.

I must now characterize the recent period from the standpoint of the economics of farm machinery—the 25 years which have passed since 1915. There are perhaps one-half dozen significant points which must receive our consideration, even though I must pass by many individual items which may ultimately be of transcendent importance. First of all, the period, 1900-40, witnessed the introduction, development, and expansion of power machinery on the farm. Incidentally, it also witnessed the all but complete disappearance of horses and mules for work and pleasure purposes in urban sections. I mention this merely because tens of millions of acres of farm land formerly used for the production of corn, oats, hay, and other grains for forage crops to be sold as feed for livestock not on farms was now available for the production of wheat and rye, tobacco, cotton, and other crops for direct human use; for the production of feed crops for poultry, sheep, dairy, and beef cattle in order to provide livestock products both for domestic use and export. By 1910 there were only 312,000 passenger cars and motor trucks registered in the entire United States, and certainly the number on farms could not have exceeded 100,000. Even these were probably largely suburban, so that substantially more than 6,000,000 farms had not yet learned of automobiles, trucks, and tractors. Indeed, relatively few had even small motors to be used for sawing wood, grinding feed, pumping water, or other farm purposes. This introduction of power machinery was then, perhaps, of first importance as the greatest revolutionary factor in agricultural economy during the recent 25-year period.

Obviously, with the development of the tractor, it was necessary to develop all of the power-drawn farm machines, plows, harrows, disks, cultivators, harvesters, and the like. The huge threshing machines, formerly operated by tremendous straw-fed steam engines, gave way to large and small tractors and threshers, and, finally, the process of threshing and harvesting was combined into one operation in machines used over vast areas.

CHANGES IN FARM EQUIPMENT PRODUCTION COST FACTORS

I come now for a moment to costs of producing automobiles, trucks, tractors, small engines, and the gasoline, rubber tires, and other accessories. If we take the prewar year, 1913, as the base period with which comparisons are to be made and designate that year with the index number of 100, according to the Bureau of Labor Statistics, four-bottom tractor plows would be indicated by the index number 98 at the time of nearly complete agricultural recovery a year or two ago. Small engines, (less than 5 hp) would be represented by the index number 88. Milking machines with the index number 78; combines (harvester-thresher) 10-ft. by an index of 75; two-plow tractors an index of 62; three and four-plow tractors an index of 61; automobiles and trucks an index of 61; gasoline an index of 38; rubber

tires, an index of 27 (prior to the imposition of a dozen excise taxes).

I have cited enough illustrations here to indicate that in spite of the tremendous increase in cost of raw materials, a corresponding increase in taxes, an increase of an average of at least 150 per cent in hourly wages of wage earners in factories, and scores of other increases, establishments engaged in the production of this important power equipment for the farms of the nation have been able to absorb all of the increased costs, and as already noted have brought the price of many machines substantially below the prices during the prewar period of 1910-15. Of course, all of this was made possible through the development of science and technology, the increase in the market which made possible mass production, the development of efficient management, and a combination of these and other factors. It is one of the most startling accomplishments in this or any other country during any period of time. Entirely aside from the unit price for all farm implements and machines, it has been found that the relative amount of farm labor needed to perform a given amount of work has been largely decreased because of great improvement in adaptability of the machinery. There is no way to measure this exactly by the use of index numbers, but its mention is none the less important.

QUALITY VALUE FACTORS NOT SHOWN IN STATISTICS

While on the subject, there are certain other aspects which call for mention. From the standpoint of statistics, a hoe is a hoe; a rake is a rake; a mower is a mower; a harvester is a harvester; in other words, a machine by a given name continues to be just a machine by that general name and description. Price statistics entirely ignore refinements. An iron or steel chisel of exactly the same size or weight costs 130 per cent more at the present time than in 1913. A disk harrow and a sulky rake each costs 110 per cent more than in 1913. A mower and a grain drill each costs 100 per cent more than in 1913. I might enumerate other items. But from the standpoint of refinements, introduction of alloys and other highly-priced raw materials, from the standpoint of adaptability, or from the standpoint of longer life or durability, the machines of today differ substantially from their prototypes of 25 years ago. I do not know that it is the duty of statisticians and economists to prepare index numbers measuring change in character or quality of items. Generally speaking, they are not qualified to do this. If it were done, it must be done by highly trained, objective agricultural engineers. But certain it is that the statistician owes it to the farmers, to the manufacturers, and their labor who are engaged in the production of these items, and the public in general, to call attention to the fact that the price statistics ignore all of these significant changes.

EFFECTIVE PRODUCTION IN FARMING AND MANUFACTURING MEANS MORE GOODS PER CAPITA

You who are in the U. S. Department of Agriculture or other government departments or in the state colleges and experiment stations, owe it as a public duty to explain points like these to the agricultural people with whom you come in contact and to the public in general, in order that they may be fully and honestly informed and so that they may not be led into making statements which are half-truths or downright false statements.

I have already directed your attention to the fact that in the short space of time since the formation of our government, the farm family has been able to not merely feed, clothe, and otherwise provide for the group living upon the farm, but now one-fourth of the population living upon the land is able to provide all of the requirements for all of the people, and, in addition, large quantities for export, and finally large quantities as industrial raw materials. I must add here that this fourfold increase in agriculture's contribution to the national welfare can be properly credited very largely to the development of tools, implements, and machines for farm use.

This is only part of the accomplishment because now all of our people have vastly more per capita than was possible in the early days. It is not so long ago that the average farmer or working family had little more than bread and butter, meat, and potatoes. They had relatively little to choose from in the way of clothing and leather products. They had relatively few of the other conveniences, comforts, and luxuries of life. Now they generally have selection from a wide range of poultry, dairy, and livestock products. They have a wide range of selection of cereal foods, and an equally wide range of selection of fruits and vegetables, both in season and out of season; and I must add that they have an equally wide range when it comes to clothing and other textile products, and the products of leather, etc. In other words, if index numbers could be formulated to measure the real progress of agriculture and the real contribution to the national welfare, the increase would not be merely 300 or 400 per cent, but would be more nearly 600 per cent in the measurement of real living standards.

CRITICISMS PROVEN UNFOUNDED

No matter what the accomplishments of agricultural engineers, manufacturers of farm implements, or others, there are bound to be cynics and critics. While many of their statements fall within the realm of agricultural economics, and might very well be touched upon here, I shall not take your time to dwell upon these unpleasant aspects of the subject more than to mention two or three illustrations in order to show how unreasonable and how untrue they frequently are. There are those who say that "farm machinery manufacturers, entrenched behind high tariff walls, are chiefly engaged in the business of exploiting the poor, unhappy farmer." It is enough here to merely state that, farm machinery for over 25 years has been on the free list. In other words, farm machinery manufacturers are not protected by tariffs. They have led the world. They do not need protection and have never asked for it. Certainly, from this angle, there is no excuse for pretending that they are either protecting or exploiting anybody. Indeed, so greatly do our manufacturers excel those of practically all parts of the world that we have a tremendous export market for farm machinery. This leads to the second point, that "manufacturers in this country systematically over a long period of years have sold and continue to sell farm machinery in foreign countries at prices far below prices charged farmers in the United States." This is equally fallacious, but I will let a series of reports made by the national government answer this statement. The national government has made several investigations and published reports stating definitely and clearly that American manufacturers do not sell farm machinery in foreign countries at prices lower than those charged farmers in this country. When these charges are dispelled, the promoters of untruths proceed with other equally groundless and false statements. One is that "all of the producers are combined into a great monopoly, having as their one purpose the making of huge profits by placing prices at excessively high levels and thus, exploiting the purchasers." Here again, it is enough to say

that the state and national governments all have adequate laws for investigation, prosecution, and supervision wherever anything in the nature of a trust or monopoly exists. And they have not failed to make the necessary investigations. But we may turn for more detailed information to the reports of the Secretary of the Treasury. Income taxes on corporations are collected year after year, and every company in the United States is required to furnish detailed facts with reference to net profits. There is no evidence here that even reasonable profits have been made. Indeed, during depression years, it is fair to say that manufacturers of farm machinery have suffered as grievously as the farmers themselves, and have made only moderate profits during average years.

You would not want me to conclude without making at least passing reference to the opportunities for the future. I have sketched hastily the story of developments over various periods of time, but space does not permit an attempt to delve into the period ahead of us. I will only say this, in my judgment the opportunities ahead are equal to all of those behind us. And that applies to the task of the agricultural engineer as well as the manufacturer of implements and machinery and the farmer. Permit me to give you one or two illustrations to bring this observation to a more definite point.

I have no doubt but that in the years to come the farmers of this country will produce millions of acres of flax and hemp for the fiber, so that the people of this country may have all of the textiles which they may desire made from linen and hemp. It would not surprise me if this country should again lead the world, as it did at one time, in the production of linen and hemp, as it has in many aspects of the cotton and woolen industries. What I have said with reference to fibers applies equally to a wide range of vegetable oils and fats. The same applies to other large groups such as starches. Perhaps equally important will be special plants now developed only slightly in this country.

One of the problems of the agricultural engineer is to lead the way. You must not sit back and wait for the farmers to first produce the article before you start planning machines for preparation of the soil, for planting the seed, for cultivation of the plant, for harvesting, and for the final separation of the valuable parts from the trash. You have before you one of the most thrilling departments of human advancement. You and your predecessors have contributed more largely than you realize to the greatness of this nation and prosperity of the world. I wish you every possible success in continuing the great work which you have been doing.

Training for Aggressive Leadership

(Continued from page 256)

some of our new specialists in the educative process, I state my belief that during the formal educational period it would be profitable to pay less attention to the pursuit of the technical and more to what may be called the simple fundamental. For example, the ability to talk well and forcefully in public is an invaluable asset to every engineer; yet how seldom has he been given training in this very thing! Naturally, not every agricultural engineer can be transformed into a Demosthenes by a semester in public speaking, but such a course certainly would help to train him to think while on his feet and to say clearly what he thought. Likewise, no engineer ever evades the need for writing well; and every engineer should be made to learn that very thing, even though he may never become a complete master of literary style. How powerful a support to a leader is the ability to write and speak well! If I had my way, I would make such an ability a fundamental requirement in every agricultural engineering curriculum.

Perhaps there is a correlation between high academic attainment and subsequent success in life; I believe there is data that demonstrates such a correlation. However, I can draw from my own observation and contacts enough instances to prove to my own satisfaction that even though a student doesn't win the highest scholastic honors, he still has practically as good a chance as anyone to become a real leader. To such individuals I would extend the strongest encouragement to study and train for leadership, for often the training they get in overcoming obstacles is the finest kind of training for leadership.

I hope that by this time I have proved the point that I set out to make: *Leadership can be developed.* It is fair to ask now, how can it be developed? Let me make my suggestions in several different directions; first, to students in agricultural engineering; second, to teachers of agricultural engineering students; third, to organizations into which these students enter for subsequent training.

To students I would say, keep out of ruts; climb the heights; know what you are doing; keep well and strong; apply yourselves diligently; look for opportunities and seize them; develop a broad outlook; become well-posted generally; learn to think clearly, to write well, to speak forcefully. Don't develop egotism, but don't hesitate to assert yourself when occasion requires. It may be all right to blow your own horn, for no one will blow it for you; but remember also that the blower is always on the small end of the horn, so be discreet.

To the teachers who have so much to do with the training of our future leaders, give your students the best balanced training you possibly can. Keep behind them most of the time; make "push" your policy, but "pull" when they get into a hole. They look to you for inspiration; try not to disappoint them. Don't cram them with useless information; teach them to think and to acquire desirable knowledge themselves. You have a priceless privilege in being entrusted with the responsibility of developing good citizens and good leaders—give them your best.

My last suggestions are to the employers of these young agricultural engineers. Don't expect too much of them in the beginning. Give them a chance to settle down and find themselves. Watch them closely, give them the guidance they need, but let them develop their own initiative. When you can, give them real responsibility; don't be afraid of giving them too much, for they thrive under it. Moreover, you may be surprised at the capacity which they may exhibit. Responsibility is the best basis for self-confidence and reliability, and one of the best aids to the development of the kind of leadership that we have been talking about.

As I view the field of agricultural engineering, I see unlimited opportunity for those who enter it properly prepared for leadership. A fair analysis of the future of agriculture will reveal most surely that the positions of greatest influence, power, and usefulness can be occupied by agricultural engineers. The field is not merely for agricultural engineers, but for *leaders,* so I say let there be real training for aggressive leadership.

Complete Electrification in Relation to Farm Income

By H. N. Stapleton
MEMBER A.S.A.E.

IT IS just as easy to show that some one individual farm can use 5000 kw-hr a month as that some other farm may not be able to use 50 kw-hr a month profitably. If profit results, it will be due to intelligence and management, not the mere fact that electricity was available, nor yet that the meter marked the month by moving over one mark on the right-hand dial.

Can complete electrification of farms make a contribution to larger farm income? The answer is Yes, qualified however by what is understood by "complete electrification" of "average" Vermont farms, and also qualified by who does the electrifying, the average farmer himself or someone else.

In the first place, a large part of the farms using electricity are not average farms. They are distinctly individual in their operation, and their requirements do not have much in common with this average Vermont farm.

Complete electrification is likewise an individual and not an average condition. Presumably the equipment used in the farm home will be within the family's ability to support the standard of living that comes with it, just as is the rest of the home. And since tastes and management ability are individual so far as their application is concerned, it seems reasonable to suppose that the "per cent saturation" will depend upon a few other things than whether electricity is free or merely low-priced as it is at the present. Complete electrification may be said to be possible, but hardly probable, if you are too exacting in your definition of "complete".

MEASURES OF FARM INCOME

Larger farm income may be measured as either gross or net. And net income may be measured in cash or in better living. If total production is not expanded, then electrification must have improved the quality of product or reduced production costs. If production is expanded, then electrification must receive credit for releasing the time from other work or for taking over the new job under automatic control. Things that affect gross profit may or may not affect the net profit. And is the contribution to be in cash or in better living, conveniences, and relief from drudgery? You may have either or both of these effects from farm use of electricity and the odds are in favor of electrification, but results cannot be guaranteed.

All this brings us to the main obstacle to the "complete" electrification of any farm. There are not enough practical ways to use electricity profitably, in spite of the fact that there are now over 300 ways in anybody's list. Furthermore, there are few farms on which the operator has the knowledge to profitably utilize more than 10 per cent of these uses.

It is probably safe to say that until electrical living becomes as popular as the motor car, there will be a lot of jobs go unelectrified. Who does the electrifying nobody cares, but until more brains can be brought to bear on these problems, don't look for any substantial increase in the present rate of progress. This is not a criticism of any person or any group. It is merely one of the sides of the whole problem.

I feel it is safe to say that, if every farm customer were to increase his number of circuits and wire size to what his load indicates he needs, he could reduce his electric bill from 8 to 15 per cent. At the same time he would improve the operation of his equipment, reduce the probability of motor burnouts, even though these motors did not have proper protection, and would decrease materially the danger of fire that always exists with overloaded wiring. In most cases, $30 to $50 would renovate 6 to 15-year-old farm wiring to practically new condition, but all an outsider can do is to explain the advantages of plenty of copper, plenty of circuits, and plenty of outlets.

Interest in food refrigeration as an item that reduces farm cash costs in feeding farm help as well as in providing family living has already fostered a lot of interest in locker storage. Farmers who use lockers have already made attempts to provide the same kind of storage at home so that they are not inconvenienced by having to make a trip to the locker plant, or at least will have some frozen storage at home.

In the home as well as on the farm, adequate light allows the work to be done better and more quickly. Ever since I saw a farm hand do a skippy job of sweeping the litter alley at the end away from the one light bulb, while he swept clean at the lighted end of the alley, I have spoken of it where farm lighting was concerned. In the farm home the manager isn't going to do much required reading and record keeping if he gets drowsy because of eye-strain within ten minutes after he sits down to that kind of work.

EXTENSIVE USE REQUIRED TO JUSTIFY HIGH EQUIPMENT INVESTMENT

There are numerous examples of equipment that has been made to fit the job profitably on individual farms. There are also some that may not fit quite so well.

There may be some perfectly good piece of equipment that you have to figure on for some time. The usual use of a 5-hp motor is one of these electrical applications bringing with it a kind of questionable economics. If there is already a tractor on the place that could do the belt jobs, wood sawing and silo filling, the tractor will only set idle while the motor works. For two week's work a year, probably an old auto engine power unit might use all of $10 worth of fuel, if you didn't have the tractor. There might be a neighbor who had a tractor he would be glad to have do those belt jobs, for a little cash or work exchanged. The motor brings with it the wiring cost, $225 for the motor and control mounted on a truck, and the power it will use. Convenient? Yes. But outside that, probably a questionable use.

Now suppose that the farm setup can be changed a little bit and this motor can hoist the hay and cure it in the barn, and the rest of the *(Continued on page 274)*

An abridgment of a paper presented at a conference of the Commission for the study of Water Resources and Electrical Energy of the State of Vermont, at Montpelier, May 21, 1940. The author is agricultural engineer with the Green Mountain Power Company and operates a farm of his own.

Reactions of Animals to Environmental Temperature, Humidity, and Air Movement

By Samuel Brody

THERE are two aspects to air-conditioning and ventilation problems, namely, (1) physiologic, concerned with responses and adaptation of animals to their environment, and (2) engineering, concerned with adaptation of the environment to the animal. Our present knowledge of the engineering aspect is far ahead of our knowledge of the physiologic aspect. It is therefore timely for engineers to meet for discussion of the physiologic aspects of the problem.

The following summary of basic facts relating to the reactions of animals to their environment may serve as an introduction to this discussion:

1 There is a minimum energy cost to being alive which is measured by heat production or heat dissipation, which is called "basal metabolism". In addition to this basal metabolism there are heat-production increases going under the names of "supermetabolism" or "heat increments" above the basal level. Thus the heat increment of feeding may double the heat production (Fig. 7); heat increment of muscular work in horses may increase heat production ten times (and for very short intervals up to one hundred times) that of the basal metabolism (Fig. 8). All productive processes, such as milk or egg production, have heat increments, partly because they are associated with increased feed consumption, and partly because there may be an energy expense to "making" the milk, eggs, and so on from their precursors.

2 The heat produced must be dissipated at such a rate as to keep the body temperature constant. In nonliving systems, the rate of heat flow from a body to its environment is directly proportional to its temperature gradient (Newton's law of cooling). Warm-blooded animals maintain constant body temperature at different environmental temperatures by various thermoregulatory devices discussed in the text.

3 Thermoneutrality is an environmental temperature at which the animal does not have to employ any of its thermoregulatory devices to keep its body temperature constant. This is because the environmental temperature is perfectly adjusted to keep the body temperature at its normal level without thermoregulatory devices. At thermoneutrality the animal feels neither hot nor cold. Thermoneutrality is a temperature zone close to the engineer's comfort zone. Its upper limit is about 85F (degrees Fahrenheit). Heat production is minimum at thermoneutrality (Figs. 5 and 6).

4 At temperatures below thermoneutrality the animal keeps warm first by physical methods, not involving increase in heat production, then, as the temperature declines, by chemical methods involving increased heat production. Most farm animals can withstand low temperatures without discomfort and without much energy expense for keeping warm, because (1) under outdoor conditions of life they develop excellent insulation against cold in the form of hair, wool, or subcutaneous fat, and (2) their winter feeds have very high heat increments of feeding.

5 At temperatures below thermoneutrality, heat dissipation is mostly (up to about 70 per cent) by radiation of infrared waves. The remainder of the body heat is dissipated by convection-conduction (10 to 30 per cent, depending on air movement and conductance of environment), and by water vaporization (20 to 28 per cent), from lungs and skin, not involving vaporization of sweat. Humidity of the environment is not an important factor in heat dissipation at the lower temperatures.

6 At temperatures above thermoneutrality (above about 85F) the burden of heat dissipation is rapidly shifted from radiation and convection to vaporization (Figs. 1 and 3). When the environmental temperature reaches or exceeds the level of skin temperature (about 95F), all the heat is dissipated by vaporization; and when the environmental temperature rises still higher, vaporization dissipates not only the heat produced by the body, but also the heat absorbed by the body from the hot environment (Fig. 2).

7 The reaction of animals to a hot environment depends mainly on their ability to sweat, and on the conditions which affect vaporization, namely, humidity and air movement. However, hot air movement is helpful only to sweating animals. Animals with dry skins are injured rather than benefitted by fanning, because the high environmental atmosphere is driven against the cooler skin, thus heating, instead of cooling, the animal. Fanning does not help vaporization from the lungs because the lungs act as their own fans. Nonsweating animals may be kept cool

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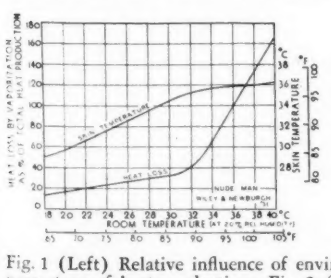


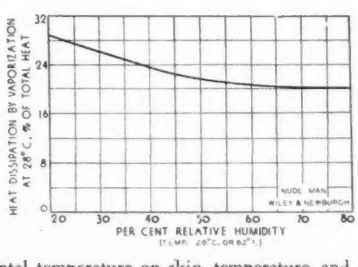


Fig. 1 (Left) Relative influence of environmental temperature on skin temperature and on the heat loss by vaporization, expressed as percentage of heat production. Fig. 2 (Center) Influence of relative humidity on percentage of heat dissipation by vaporization at 28C.

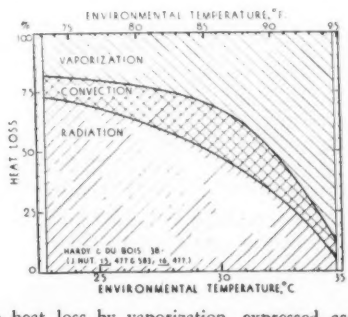
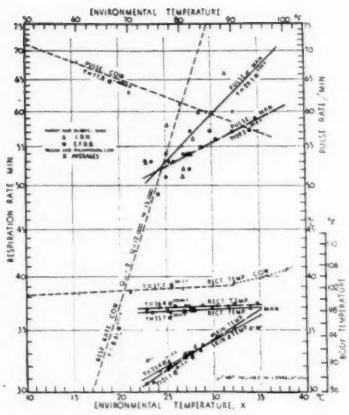


Fig. 3 (Right) Influence of environmental temperature on the percentage of heat loss by radiation, convection, and vaporization



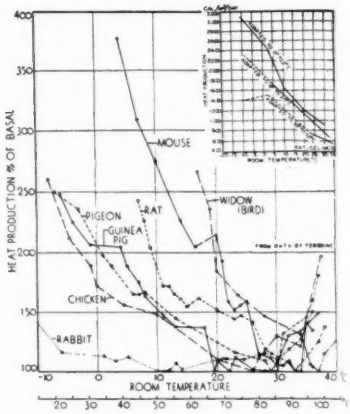


Fig. 4 (Left) Relative influence of environmental temperature on pulse rate and rectal temperature in man and cow. Influence of environmental temperature on skin temperature of man, and respiration rate of cow. Fig. 5 (Right) Influence of environmental temperature on heat production of resting animals in postabsorptive condition. Influence of environmental temperature on heat production on rats acclimatized to different environmental temperatures

by keeping their skin moist and fanning them only when the skin is moist. Sweating animals may be kept cool by fanning and, if possible, dehumidification. A prime factor in keeping cool in all cases is to reduce the heat increments of muscular exercise and of feeding in the heat of the day. The importance of sweating and of keeping the skin moist for keeping cool is indicated by the fact that, in sweating animals, from 40 to 95 per cent of the vaporization is from the skin. Nonsweating animals resort to panting in hot weather in order to increase vaporization rate.

Keeping Cool in Hot Weather. There is only one method for keeping cool in a hot environment, namely, by vaporization of water from lungs and skin. For every quart of water vaporized from the body, about 600 Cal or about 2400 Btu, of heat are dissipated. The amount of vaporization from an animal depends on its ability to perspire, and on the dryness of the air. Speed of movement of the air, as produced by fanning, also facilitates vaporization from animals that lose water from the skin, but does not appreciably facilitate vaporization from the lung, because the lung acts as its own fan. In sweating species, such as man, about two-thirds of the total vaporization is from the skin, and about one-third from the lung. In nonsweating species, most of the vaporization is from the lungs.

The engineering problem of keeping animals cool in hot weather is quite different for sweating than for nonsweating animals. A good fan may keep a sweating animal comfortable. But a fan will do little good to keep a sheep, cow, or dog cool, because it will not greatly facilitate vaporization from the skin. Nonsweating animals, such as cattle, could probably be cooled by vaporization as well as sweating animals, by keeping them moist by sponging or covering with a wet blanket, and fanning. It is suggested that facilities for this manner of cooling be extended to high-producing dairy cows that are particularly in need of cooling because of the high heating value of their feed.

Fig. 4, prepared on an arithlog grid from data by Hardy and Du Bois[3]* and from Regan and Richardson[4], shows the relative influence of environmental temperature on a sweating species, nude man, and a nonsweating species, dairy cow.

It seemed instructive to fit equations to the data. The equation for the increase of respiration rate with increasing environmental temperature in Regan's cows shows that for an environmental temperature increase of 1C, the respiration rate increased by 7.1 per cent; or for a 10C increase, the respiration rate increased by 71 per cent on the instantaneous-rate basis, or near 100 per cent on the finite-rate basis. In other words, the respiration rate of the dairy cow is doubled by increasing the environmental temperature by 10C or 18F. This is conventionally represented by the equation $Q_{10} = 2$, and when $Q_{10} = 2$ to 3, it is known as the Van't Hoff law for the influence of temperature on the speed of chemical reactions. It is difficult to say whether the applicability of the Van't Hoff or the Arrhenius equation (in which equation $\mu = 12{,}000$ to $13{,}000$) to the change in respiration rate with increasing environmental temperature is a fortuitous coincidence, or whether it has ulterior biochemical significance. From *a priori* considerations one would expect that the Van't Hoff - Arrhenius equations might apply to the relation between respiration rate and body (rectal) temperature, and not environmental tempera-

*Superscript figures refer to literature cited at the end of this paper.

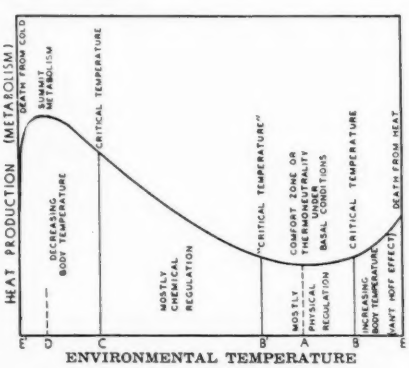
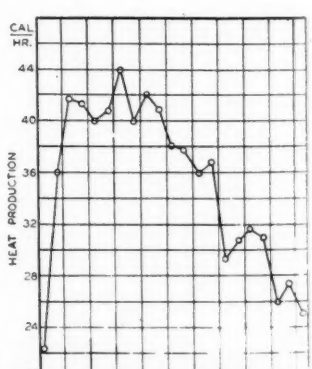


Fig. 6 (Left) Diagrammatic representation of the reactions of animals to changing environmental temperature. Fig. 7 (Right) The rise and decline in heat production following the consumption of a meal of meat by a fasting dog



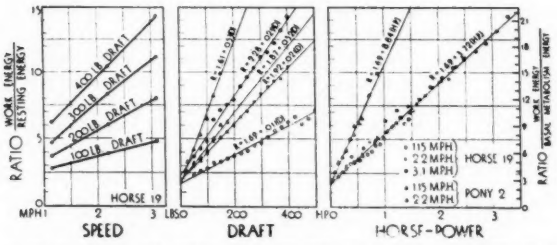


FIG. 8 THE RISE OF HEAT PRODUCTION IN A LARGE HORSE AND SMALL PONY WITH INCREASING RATE OF WORK

ture. Fig. 4 also shows important differences in the influence of environmental temperature on pulse rate in sweating man and nonsweating cow.

Overheating in Hot Weather. An animal is said to be overheated in hot weather when its rectal temperature and pulse rate rise above their normal levels. Such rise is often followed, especially in the aged, by collapse, variously referred to as heat exhaustion, heat stroke, and sun stroke. The collapse may be due to the high temperature as such, but more often it is the result of circulatory failure[2,5], partly as a consequence of the strain imposed on the heart of sweating animals by the necessity of more rapid circulation of the diminished blood available for the heart.

Another type of hot-weather disability which occurs in sweating animals in a *dry* environment is *heat cramp*. The outstanding symptom of heat cramp is disabling pain in the muscles, including the heart muscle. This disability is the result of excessive loss of salt in the sweat. The serum chlorides are reduced from 2 per cent in the mild cases to 10 per cent in severe cases[6]. Loss of salt is necessarily associated with loss of water, otherwise the osmotic pressure would change. Farm animals that have access to salt probably never develop heat cramps because, unlike humans, animals develop a salt craving and consequently satisfy the salt need.

Keeping Warm in Cold Weather. Unlike protection against heat, protection against cold is not influenced importantly by humidity, because heat dissipation in cold weather is mostly by radiation and convection, and but slightly by vaporization (Fig. 3), although below 45F, humid air feels colder than dry air because the conductivity of the clothing is increased. The body has more defenses against injurious effects of cold than of hot environments.

If the temperature is gradually lowered, as occurs in nature with change in season, the animal reacts to the change by developing various types of insulating coatings, such as wool, mohair, feathers, bristles, or subcutaneous fat, which are, incidentally, also important agricultural products. Certain behavior patterns are adapted to preserve body heat, such as curling up, covering up, seeking shelter, seeking sunlight, huddling together (so-called social temperature regulation[8]).

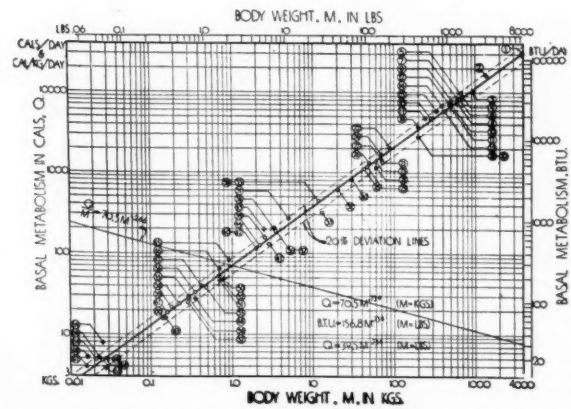


FIG. 9 THE RELATION BETWEEN BASAL HEAT PRODUCTION AND BODY WEIGHT OF MATURE ANIMALS OF DIFFERENT SPECIES

When the temperature decline is rapid, nervous mechanisms are called upon, such as those involved in contracting the surface blood vessels, thus removing the blood from the surface and protecting it from cooling.

If the above physical methods of thermoregulation are not adequate for maintenance of normal body temperature, then chemical mechanisms are employed, namely, increased heat production due to tensing of muscles, shivering, increased voluntary exercise, and also increased production of metabolic hormones, particularly adrenalin[9] for more rapid environmental changes, and thyroxin[10] for slower environmental changes.

Ease of keeping warm in a cold environment depends on several other factors, of which body size is one. It seems that since heat loss is by way of the surface area, and since the ratio of surface area to body weight decreases with increasing size of animals, the larger the animal, other conditions being the same, the less heat it loses in comparison to its weight, and the easier it can keep warm in a cold environment. The influence of body size on heat production at different temperatures is illustrated by Fig. 5.

For any particular animal, the thermoneutrality zone will obviously depend on season (that is, temperature to which the animal is acclimatized), humidity, air movement, and other factors such as species, age, sex, state of nutrition, state of health, and so on.

As the environmental temperature is lowered or raised on each side of this zone of thermoneutrality, the heat production is increased. Increase in heat production, especially with the decrease in environmental temperature, is, on the average, more rapid in small than large animals. Note from the inset in Fig. 5, also that if the animal is adapted to live at a low temperature, it produces more heat at any temperature than if it is adapted to live at a higher temperature. It takes time to change the organic thermostat from one to another heat-producing level[11].

Diagrammatic Summary of Thermoregulation. What happens if the environmental temperature continues to increase or to decrease? Obviously, sooner or later, the environmental temperature will become too cold or too hot for the animal to survive and it will collapse.

Fig. 6 illustrates in diagrammatic manner how the situation works out. There is a zone of thermoneutrality between the environmental temperatures B′ and B, with the theoretical point of thermoneutrality at temperature A. If there is any thermoregulation between B′ and B, it is physical, that is, the change in heat production (chemical temperature regulation) is inappreciable. The body temperature remains nearly constant between the environmental temperatures C and B′; declines when the environmental temperature is lowered from C to E′; and rises when the environmental temperature rises from B to E.

It is instructive to observe that the environmental temperature range A to E′ (thermoneutrality to fatal cold) is very much wider than temperature range A to E (thermoneutrality to fatal heat); that is, the adaptive powers to cold are very much greater than to heat. This is of course particularly true of the nonsweating, furry, relatively large animals such as sheep, cattle, and dogs. Practically, this

means that it is not so difficult or important to protect an animal from cold as from heat.

As previously noted, the temperature regulation in the comfort zone BB′ is by physical methods, the change in heat production being inappreciable. Beyond BB′ there is increased heat production with decreasing or increasing environmental temperature. However, there is a radical difference in the causative mechanisms for the rise in heat production with declining and rising environmental temperature. The rise in heat production between B′ and D (decline in environmental temperature) is biologically desirable—is indeed a physiologic adaptation in order to maintain the body temperature constant; while the rise in heat production between B and E is biologically harmful, taking place in spite of its harmful effect, as a physico-chemical necessity (as defined by the law of Van't Hoff, according to which the speed of chemical transformation is doubled for a temperature increase of 10C).

Thermal adaptability of an animal is measured by the ratio of maximum (summit metabolism) heat production of Giaja[13] at environmental temperature D in Fig. 6 to basal heat production at environmental temperature A.

There are great species differences in the ratio, summit metabolism to basal metabolism. There are also great age differences in this ratio. There is no need for adaptability before birth because this is taken care of by the mother. Following birth the adaptability is gradually developed with the assistance of the mother, who tides over periods of chilly spells. Birth or hatching normally occur during seasons of the year when the environmental temperature is optimal for survival of young. When hatching or birth is adjusted to occur at some other season of the year, the breeder has the problem of supplying artificial heat, as for example, for brooding chicks.

There is a steady decrease in the temperature range in which animals can survive (that is, in the ratio of summit to basal metabolism) following the prime of life. It has been long known[14] that heat production (basal metabolism) decreases with aging. Lessened adaptability to heat is probably due to degenerative changes in the skin, with its sweat and sebaceous glands and other cooling mechanisms, and to sclerosis of surface blood vessels.

HEAT INCREMENTS OF FEEDING AND WORKING IN THERMOREGULATION

All productive processes, such as milk and egg production, necessarily involve extra feed consumption, and therefore all productive processes necessarily have heat increments of feeding (Fig. 7) in addition to possible heat increments of "making" milk, egg, meat, etc. Even mere maintenance feeding involves extra heat production. Highly unbalanced feeds, such as straw or poor hay, have particularly high heat increments of feeding. They are therefore useful for wintering animals, to keep them warm, although of course such feeds are useless for productive purposes.

The above discussion makes it evident that large farm animals with access to plenty of feed are not likely to suffer from winter cold in most localities of this country. Heat increments of feeding and working (Fig. 8) should be reduced in the summer by avoiding unbalanced rations and physical exertion in the heat of the day.

Influence of Body Size on Heat Production. A 200-lb animal produces not twice as much heat as a 100-lb animal, but only about one and two-thirds times as much. This is illustrated in Fig. 9 for animals under basal conditions. Under normal maintenance conditions the heat production may be 50 per cent above the basal level, depending of course on the activity level under the basal conditions. Under productive conditions, such as lactation, gestation, growth, muscular work, the heat production is still greater, depending on the level of productivity and feed consumption as previously explained. The important idea is that the heat production, no matter on what level, is not directly proportional to body weight, but to about the 0.73 power of body weight.

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Techniques of Hydrologic Research

By H. S. Riesbol
MEMBER A.S.A.E.

EXISTING techniques utilized in hydrologic research have developed from needs by various professions for specific information concerning the processes of hydrology. The agricultural engineering branch of the engineering profession, through its work in irrigation, drainage, flood control, farm water supply, soil conservation, and crop production, requires a variety of information which includes nearly every ramification of the science of hydrology. In the present status of the science, techniques are not available for accurate quantitative analysis of all its processes. It is therefore necessary for the practicing engineer to become familiar with the basic techniques now applied in research, if he is to utilize the products of research in a successful and intelligent manner. I do not intend, in this paper, to describe and define all the available techniques of direct measurement and mathematical analysis, but rather to discuss procedures which promise results of immediate value to the agricultural engineer.

The expansion and refinement of existing techniques and development of new procedures, as needed to establish the basic dynamic relationships between biotic factors and activity and the hydrologic processes, are attracting the attention and efforts of many workers in the field of hydrologic research. Such techniques will supplant and supplement those suited particularly to the evaluation of net hydrologic results. These have developed in the past as the result of urgent need for hydrologic data which could be applied immediately in engineering design on an empirical basis without waiting for the discovery and confirmation of basic laws and relationships.

An example of this is offered by the study of interception, in which most of the early investigators sought merely to evaluate the total quantitative catch of precipitation by plant canopies, whereas present workers are more interested in dynamic effect resulting from changes in rate of movement, impact of fall, drop size, and other related characteristics as caused by the physical properties of the plant canopy.

This desire to interpret the effect of biotic influences upon hydrologic processes through refined and improved techniques has resulted in the need for and development of instruments capable of continuous and accurate recording of various hydrologic phenomena. Records from such instruments, when secured on an open scale and with a high degree of synchronization between the various instruments, must be subjected to careful and detailed application of mathematical and statistical techniques to fully interpret the rate-time or accumulated volume-time relationship expressed by the particular graph.

For the purpose of this discussion a familiar grouping of the processes of hydrology is taken as follows: (1) Precipitation, (2) interception, (3) surface storage, (4) runoff, (5) infiltration, (6) storage of soil water, (7) percolation, (8) storage of ground water, (9) evaporation, and (10) transpiration. It is assumed that every engineer is familiar with the general interpretations of these terms and that his requirements for data and information will be controlled by the type of work peculiar to his particular professional division. The techniques of hydrologic research, regardless of the professional application which is to be made, have developed around the measurement and correlation of these processes.

The measurement of precipitation in any form is essentially a technique of securing representative samples with sufficient replication to insure reasonable limit of error. For the free-falling forms of rain, snow, hail, and sleet, such methods are well established, although admittedly subject to improvements. Considerable study has been directed toward determining the proper distribution of rain and snow gages, both recording and nonrecording. In this connection the intensive application of isohyetal maps to rather large areas covered by a close network of recording gages has permitted Thornthwaite[1]* to secure valuable in-

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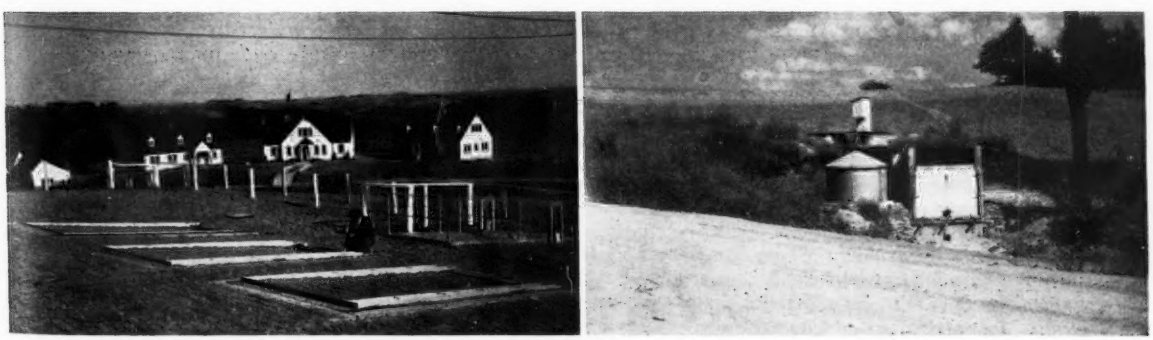
*Superscript figures refer to literature cited at the end of Mr. Riesbol's paper.



EQUIPMENT FOR GETTING HYDROLOGIC DATA ON SMALL AREAS

(Left) Surface view of one battery of watercycle lysimeters on a 14 per cent slope, Muskingum soil at the North Appalachian Experimental Watershed. The administration building, soils laboratory, and engineering building of the project headquarters may be seen in the background. (Right) Type-H measuring flume with recorder silt box and Ramser silt sampler for measuring rate and amount of runoff and total soil loss from a small watershed located on the North Appalachian Experimental Watershed project

formation concerning the distribution of precipitation and of storm morphology over an area. When such maps are prepared in sequence for comparatively short time intervals, they provide a time-area-depth relation from which the source of water available for surface runoff may be determined. This latter usage is parallel to the familiar Thiessen method for giving each precipitation gage areal significance through geometrically established influence areas.

Wilm and others[2] have utilized the isohyetal map plus computed least squares interactions to estimate the desirable spacing of gages for a given degree of accuracy of catch on a depth-area basis. Their study was also extended to estimate the effects of aspect and slope. Information of this type is needed in all parts of the country to establish a sound basic technique for the location and spacing of precipitation gages.

The best exposure, enclosure, and most satisfactory shield or other artificial draft protection for the individual gage have long been the objectives of intensive research by both American and foreign investigators as summarized by Brooks[3]. Many workers agree that establishment of standard shields or enclosures and of a technique for correcting records from gages not so equipped is needed for gages located in exposed areas subject to strong wind action or to updrafts.

Improved recording rain and snow gages which may be read to the nearest minute of time have made possible the determination of rainfall intensities for short time intervals. Intensity-frequency curves established from these data are of vital importance to the agricultural engineer in his design of hydraulic structures.

Precipitation due to condensed moisture as fog, dew, or frost probably occurs in appreciable amount, but satisfactory methods of measurement have not been developed. Estimates of this type of precipitation have been attempted through potometers and weighing lysimeters, but the methods are still in the experimental stage. A technique for these studies should be particularly sensitive to the influence of various vegetative types.

EFFECTS OF INTERCEPTION OF PRECIPITATION

The interception of precipitation by foliage, twigs, and branches of trees, shrubs, and other vegetation is a direct subtraction from precipitation reaching the ground surface. It causes radical change in drop size, impact, and other physical characteristics of ground rainfall. The most common technique utilized in the measurement of interception is to obtain a dependable sample of the precipitation over the vegetative canopy and another under the canopy, at the same time measuring stream flow, so that the net difference may be charged to interception. Interesting summaries of studies of this type have been prepared by Horton[4] and Davis[5]. Most of these observations have been made on forested areas, but are not of sufficient scope to delineate the detailed interrelations between the characteristics of vegetation and precipitation. Other measurements of this process have been made for agricultural crops by completely paving the ground surface under the crop canopy on a small area, then measuring the runoff from this area and the precipitation above it. The net difference again represents interception. More precise and comprehensive techniques for the study of interception by all types of cover are urgently needed and should be developed along three lines of approach: (1) study of changes in the physical characteristics of precipitation as it passes through the plant canopy, (2) the volumetric subtraction from precipitation by interception on an areal basis, and (3) the physical characteristics, such as intensity, duration, and amount of precipitation reaching the ground surface under the canopy.

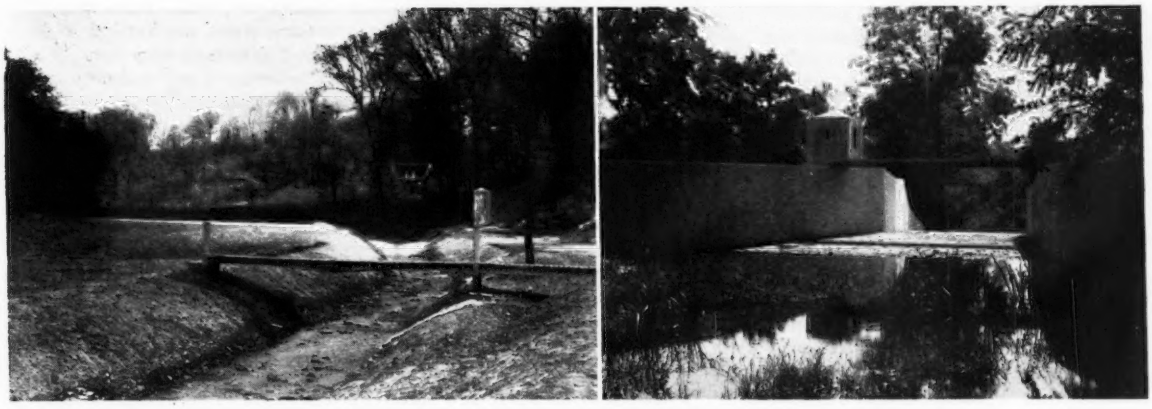
Surface storage of water as snow during the winter months is of particular interest to irrigation engineers. Excellent techniques for snow surveying as utilized in estimation of water yield for irrigation and water supply are now available as described by Clyde[6] and Church[7]. These procedures have required ingenuity in the design of special sampling equipment such as the core cutting tube and snow scales, and in establishing standards for the location and frequency of samples on selected routes.

In the agricultural areas of the Middle West the engineer has paid particular attention to the storage or conservation of moisture for the production of crops. This has been partially accomplished through the practical application of hydrologic principles, namely, that increased surface detention and retention of water increases the opportunity for infiltration and that increased infiltration provides opportunity for the storage of more water in the soil. This has led, in research, to the development of such conservation practices as closed-end level terraces, contour furrows and listing, waffle cultivation, etc., all aimed at increase of surface storage of water during storms. Techniques for evaluating the effects of these practices have included routine soil moisture measurements involving periodic sampling to various depths, determination of crop yields and rate of plant growth as indices of available moisture, and measurement of rainfall and runoff during storms to determine the retention of water by the field. Additional techniques are needed to evaluate surface detention depths and velocities of overland flow as they relate to the surface storage process, and particularly as affected by cover and tillage characteristics.

PROGRESS IN MEASURING AND PREDICTING INFILTRATION

Many workers, during recent years, have made rapid progress in the study of "infiltration". It is at the same time unfortunate that there is considerable technical disagreement regarding the actual meaning of the term and the significance of the results obtained from the various direct measurements. For this discussion infiltration is regarded in general terms as the process by which water, in either liquid or solid state, passes downward through the exposed surface of the earth into the zone of aeration. Measurement of infiltration, both in rate and amount, is accomplished through two general techniques, namely, (1) a sampling procedure wherein direct values of infiltration are secured at sufficient representative specific points in an area to establish an average value for the area within certain limits of error, and (2) the area-depth estimates secured from analysis of the runoff hydrograph. This latter technique is again mentioned later in this paper.

The accuracy of the sampling technique for evaluating infiltration on an areal basis is probably most limited by the accuracy of the device used for making the specific measurements. Such devices are classified in two broad groups, namely, (1) those which maintain uniform surface detention over an area of a few square inches by supplying water at a rate equal to the infiltration requirement, of which the Musgrave tube[8] and Kohnke grid[9] are examples, and (2) those which apply simulated rainfall at constant and known rates over plot areas of a few square feet, infiltration being obtained by analysis of the resultant rainfall-runoff hydrograph.



EQUIPMENT FOR MEASURING RUNOFF IN TRIBUTARY STREAMS

(Left) Stream flow measuring station of the type rated by current meter discharge measurements. The station consists of concrete shelter for recording instrument, Columbus deepnotch ogee weir, and cableway and footbridge from which discharge measurements are made. (Right) Dual Parshall measuring flume of 15-ft throat width for the measurement of runoff in rate and amount from a watershed of 125 acres drainage area, North Appalachian Experimental Watershed Project

Infiltration rates are controlled to a large extent by soil surface conditions which are, in turn, controlled by cover and tillage. It is therefore apparent that techniques which will thoroughly establish significant infiltration values are essential before the influence of agronomic practices in the processes of hydrology can be fully understood.

The term "suspended water" as commonly used refers to all water in the zone of aeration, including hygroscopic water, capillary water, and gravitational water, but excluding water of hydration. Soil water contains the same forms but lies only in that zone from which water is discharged into the atmosphere in perceptible quantities by transpiration and soil evaporation.

Accretions to suspended water occur almost entirely through the process of infiltration, and therefore the techniques for the study of both processes are closely related.

Decretions from suspended water may be generally classified as (1) downward percolation into the zone of saturation, (2) lateral seepage into surface channels, (3) evaporation from the soil surface, and (4) transpiration by vegetation. Techniques for the study of these factors are briefly discussed elsewhere in this paper.

Methods for actually evaluating on an areal basis the amount of water contained in the soil at any time are based on a sampling procedure which requires representative measurements secured with proper distribution and with sufficient replications to be within a reasonable limit of error. One common procedure is that of taking actual samples of the soil to specified depths within the soil solum, and then drying these samples in an oven. This method is, of course, intermittent in nature and is limited on an areal basis by the amount of labor necessary to the taking and analyzing of the samples. Many workers are now trying out various approaches toward the perfection of an instrument which will record moisture content at any point in the soil directly and continuously. Noteworthy among these are the tensiometer[10], the Richards soil moisture meter[11], and, recently, the heat conductivity device designed by Baver and Shaw[12].

The interpretation of hydrologic data to demonstrate the effects of soil characteristics and land-use practices will be made more simple and dependable when a practical technique is available for the evaluation of soil water on an areal basis and continuously with time. The term "continuously" is emphasized since only through continuous measurements can the storage factor be fully equated on a volumetric basis with the other measured processes such as precipitation and runoff.

Percolation, the process by which water flows through soil and geologic material, is so intimately associated with storage of water in the zone of saturation that the techniques for study of the two processes must be discussed together.

Accretion to ground water, which is defined as water in the zone of saturation, occurs largely as downward percolation from suspended water in the zone of aeration, by lateral and downward percolation through porous materials from saturated zones at higher elevation, by direct inflow through crevasses, and through other contributions of usually minor nature. Methods for the evaluation of these accretions are associated to a large extent with the study of infiltration and storage of soil water as previously discussed. Actual rates of lateral flow of percolating waters have been studied through various techniques, among which are (1) determination of time required for dyes or electrolytes introduced in one observation well to move to adjoining wells[13], and (2) estimation of volumetric rates of percolation through pumping tests by the Thiem method[14]. Downward rates of percolation are measured with various types of lysimeters, by laboratory methods, and by observation of ground-water levels in wells.

Decretions from ground water occur in the greatest degree as seepage and spring flow directly into surface channels, as subsurface flow to other ground-water tables, and as direct evaporation and transpiration when the water table is close to the surface. Techniques for the study of these processes are discussed elsewhere in this paper.

Volumetric fluctuations in ground-water storage are studied by several methods, most noteworthy being those referred to in this paragraph. The depth to water table in observation wells is recorded and the change in level during any time period is then multiplied by the average porosity of the geologic material to obtain volumes of water involved in the process. Determination of the average porosity requires the taking of many samples at great expense and often with results of questionable accuracy. The base flow depletion curve of a stream, as obtained at any gaging station, may be integrated from zero flow to any

desired point on the curve to determine the ground-water storage yet available in the drainage basin at that point for stream flow. This technique has been developed largely by Snyder[15]. As used herein, base flow is that portion of the flow in stream channels which is derived from ground water and the depletion curve is a line representing the rate of decline of base flow during periods of no accretion to ground water.

The literature contains many references to techniques for the evaluation of evaporation and transpiration in connection with specific experimental objectives. Rarely, however, is there reference to a method which will estimate the quantitative activity of these processes on an areal basis with a known and dependable limit of error. The two processes are considered practically as one in all present methods for evaluating them on agricultural areas. Quite precise procedures are available for the calculation of evaporation from open water surfaces.

Probably none of the hydrologic processes are so clearly expressive of biotic activity on an area as are evaporation and transpiration, since they represent the actual water losses due to the life processes of the soil and plants. Techniques to correlate the physical and even the chemical characteristics of soils and plants with the quantities of evaporation and transpiration which are experienced under various atmospheric and climatic conditions, will be of substantial economic value to the agricultural engineer in his various activities.

Raber[16] has prepared a comprehensive review of the literature dealing with water utilization by trees in the north temperate zone and describing methods of measurement. A similar review dealing with water utilization by agricultural crops is needed. Most of the procedures for study of evaporation and transpiration may be classified as follows: (1) artificial supply of water to whole plants or parts of plants in the laboratory, (2) the growth of plants in small containers (potometers) which are weighed periodically to determine losses[17], (3) the use of watercycle lysimeters[18] which measure rate and volume of precipitation, runoff, percolation, and additions to and subtractions from soil moisture for blocks of undisturbed soil supporting agricultural crops, and (4) studies of soil moisture depletion during periods of no rainfall. Thornthwaite[19] has recently developed a technique whereby evaporation and transpiration from fairly large fields of agricultural crops may be computed from continuous records of temperature, humidity, and wind movement obtained at different and specified elevations above the crop canopy.

RELATION OF RUNOFF TO OTHER HYDROLOGIC PROCESSES

Runoff is often defined as that portion of the precipitation which flows from an area in surface streams, in either natural or artificial channels, at or below the ground surface or through the ground. It is generally recognized that runoff is a precipitation residue remaining after the requirements of other hydrologic processes have been satisfied. This suggests that when proper techniques are applied to the measurement and analysis of runoff, certain information will result concerning the other hydrologic processes. As used herein runoff refers to volume, generally inches in depth over the area, and flow to rate, generally cubic feet per second.

Measurements of runoff have, in most studies, been limited to the channel phase, that is, to runoff which takes place in surface channels and which is governed by the laws of flowing water in open channels. Flow determinations by current meter stations, weirs, flumes, and so forth, represent basic methods familiar to most engineers. Studies in connection with water conservation and soil erosion control require runoff measurements on small agricultural areas which, in turn, necessitate improvement of the basic techniques to meet three specific conditions: (1) extreme flash flows involving rapid change in stage and slope; (2) flows carrying heavy silt which increases the apparent volume, fills stilling basins, and chokes measuring devices; (3) great difference in rate of long-sustained base flow and of maximum flood peaks. Special flumes and other equipment have been developed which apparently satisfy conditions (1) and (3). Further work should be directed toward development of devices for accurate and continuous measurement of heavily silt-laden flows.

RUNOFF RATE AND VOLUME CHARACTERISTICS

Techniques for the analysis of runoff data are centered about either rate phenomena or volume characteristics. Associated with volume studies are methods which evaluate runoff by seasons, years, or other periods of time through the application of various statistical and probability procedures such as the flow-duration curve used by Meyer[20] and others. Rate phenomena have been extensively investigated through analysis of the runoff hydrograph, which has required development of techniques for the following purposes: (1) to separate base flow from overland flow and from flow which originates as seepage from the zone of aeration, (2) to convert the channel outflow graph of overland flow and seepage flow at any point into a channel inflow graph for the drainage area, which is accomplished through correction of the hydrograph for storage in stream channels and valleys, and (3) to analyze the channel inflow graph for surface detention, rate of overland flow, and basin retention. These factors are expressive of the dynamic relationship between the hydrologic processes and cover, soil, and tillage influences.

The depletion curve is established on a seasonal basis and then projected under individual storm hydrographs to estimate the separation of base flow from storm flow. This technique has been studied in detail by Horton[21] and others. Other investigators are attempting to establish the base flow hydrograph by correlation with observed levels in groundwater observation wells and observed flow from springs but as yet the methods are not well established. Techniques for correlating base flow with soil moisture and precipitation are needed to fully interpret agronomic influences and daily and seasonal fluctuations.

Two general approaches have been developed for correcting the observed storm-flow hydrograph for channel storage to obtain channel inflow. Most accurate evaluations of storage can be made when a given reach of a stream is isolated by sufficient stream-flow measuring stations to reduce the unmeasured inflow to that coming in over the stream banks. Under this condition inflow into the reach at any time can be balanced against outflow for the same time, the difference being ascribed to gain or loss in storage. The second approach is applied when only one measuring station is available for the measurement of stream flow from a given area and consists of plotting a curve to relate volume of storage and rate of discharge from integration of the recession side of the hydrograph.

Extensive work has been done during recent years on the correlation and analysis of rainfall and runoff records

both on a seasonal and storm basis. Many of the techniques of plotting and tabulating such data on a seasonal and annual basis are familiar both to the agriculturist and engineer, and therefore need not be repeated here. Meyer[20] and other writers on hydrology have listed many of these procedures.

Rapid strides have been made in the development of techniques for the analysis of rainfall-runoff relations during storms. Ramser[22] has studied the time of concentration which he refers to as the time "required for the water to travel from the most remote point of the watershed to the outlet or gaging station," and of volumetric relations of rainfall and runoff for given storms. Horton[21] has explored in detail the analysis of the hydrograph utilizing the "infiltration theory of runoff." From hydrographs showing the rate and accumulated amounts of rainfall and runoff and by estimating, on a trial-and-error basis, the infiltration capacity of a drainage basin, he has been able to determine the initial losses, average surface-detention depths, velocity of overland flow, and other factors. In this procedure the channel inflow graph as previously described is used as an expression of surface flow from the area.

Sherman[23], Bernard[24], Hoyt[25] and other have studied the unit hydrograph or distribution graph as a tool for estimating runoff rates and volumes from known precipitation and also as a method for analyzing rainfall runoff data from experimental watersheds. The unit hydrograph is defined as the hydrograph of direct runoff resulting from rainfall within a unit of time, as a day or hour. A distribution graph is a unit hydrograph of direct runoff modified to show the proportional relations of its ordinates in percentage of the total direct runoff. Direct runoff in these definitions refers to the total amount of surface runoff and subsurface runoff which reaches stream channels. Subsurface runoff includes water which enters the soil but returns to the surface or appears in channels at a lower level without entering the ground-water table in the zone of saturation.

Numerous other methods for the study of rainfall runoff relations by mathematical techniques for either prediction purposes or to estimate other hydrologic processes have been presented in the literature, but in many cases they are still in the experimental stage of development, or do not promise results of direct utility to the agricultural engineer. This same statement applies in large measure to techniques which have been omitted in the discussion of other hydrologic processes.

SUMMARY

A critical review of the techniques utilized in hydrologic research leads to certain specific conclusions and suggestions: (1) The methods for measuring the activity of the hydrologic processes on an areal basis have not advanced to an equal degree of ability for all processes. Rainfall and runoff, for example, can be measured much more accurately over a large area than can soil moisture or transpiration. (2) In many cases the techniques now available do not provide for tracing the dynamic activities of any process throughout its occurrence or for correlating such activities with the biotic influences of soils and cover. (3) Many workers are now engaged in developing methods and procedures which will eventually overcome the shortcomings mentioned in (1) and (2). It is the hope of every hydrologist that such development will lead as rapidly as possible to additional techniques which will permit the complete quantitative analysis and establishment of basic theoretical relationships between all the processes of hydrology on a watershed or other areal basis.

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Complete Electrification in Relation to Farm Income

(Continued from page 264)

summer pump water on the pasture once in a while to keep it in June condition until frost, in addition to doing the wood sawing and silo filling. You could begin to get somewhere with your investment in a 5-hp motor. You could, because of your improved hay and pasture, save on the grain bill, and because your cows could use the pasture longer, the tonnage of dry feed handled in the barn would be less. By that same amount there would be less manure to haul back to the fields. While there seems, at present, no practical way to do field work electrically, there may be an application of electricity that will eliminate some of the field work that used to be necessary.

When I say that research and development are a necessary part of progress in rural electrification, I mean that we should be working on the idea of making the "electric method" fit the job, rather than that we should be satisfied with merely "electrifying" that certain job. Up to now, most of the work that has been done has been in electrifying, that is, putting a heating element or a motor on the same old equipment that has always been used. I believe that a certain amount of effort on the question "How must this job be done by the electric method?" would give some real results.

I also feel very sincerely that more should be made of the electric method. Incidentally, as the electric method is applied to a larger number of farm and home jobs, the current use per month is likely to go down instead of up, at least on individual applications.

In the present electric range, heat is applied in the same way that flame-burning devices have applied heat, to the same pans that have been used since the bronze age. And yet there is on the market today a set of range units and kitchen ware that cooks by induction heating, with quite an improvement in efficiency over the ordinary range units and kitchen pans. The same iron loss that contributes to energy losses on service lines has become, by multiplying its effect, a more efficient way to cook food.

To illustrate how we all take progress for granted and severely discount the hard work, time, money, and headaches involved, I am going to predict that at a meeting such as this in 1950, some young fellow just getting started in electrification is going to get up and talk about the high price of electronic-tube kitchen ranges. In the next ten years the manufacturers will have taken the artificial fever machine, put a cooking top and oven on it, fitted it out with pyrex dishes for new brides, and will be calling it the last word in kitchen equipment. A photoelectric cell "tuned" to the color the food should be when it is done, will shut off the current when the food is cooked. The heat will be generated within the food itself instead of being applied to the pan, and after all that is what you want if you are trying to cook food. If you think this sounds too much like a figment of the imagination, please remember that the same electronic tube has already given us radio, the trans-Atlantic telephone, sound movies, television, the supermicroscope, and a score of other things.

AN OUTLOOK TOWARD MORE COMPLETE ELECTRIFICATION

I believe you will agree that it cannot be emphasized too strongly that there is need of a lot of ingenuity and man-hours being put in on finding the electric method for the particular job. And that is less than half the job that needs to be done. In today's so-called "modern" houses the kitchen is usually the most liveable room in the house. It ought to be. In the past ten years it is the room that has had the most thought and effort put on it. The result is a room designed for electrical living. It makes use of modern equipment, and you can put all of it in at once, or you can add a piece at a time, and you come up with the same thing—beauty, convenience and utility all through the room.

If we are ever to have farm operation that utilizes "complete" electrification, we are going to have to do the same thing for the entire farm building group. We shall have to redesign the farm around the electrical equipment that will make it as completely modern as the all-electric kitchen. Some of you production men might like a shot at this little problem.

In taking care of one cow in the stable from October to May and milking her there during the other four months you do some heavy lifting, even though the carrying depends on how well your present stable is arranged. These amounts are conservative, so if you think my figures small, just add to them. First there is, or ought to be, if the cow is any producer at all, at least 3 tons of milk. You will have to put up 2½ to 3 tons of hay. A hay loader and a horse fork may get it into the mow for you, but you still have to dig it out of there and put it into the manger. I hope you let electricity or gravity supply the water. From October to May a cow drinking 20 to 25 gallons of water a day drinks from 17 to 20 tons of water. There will be from ½ to ¾ ton of grain to handle, and if silage is fed, that will run from 2 to 4 tons. Then you go back of the cows and shovel most of that tonnage out and spread it on the field so you can grow more hay next year. The cow is really quite a remarkable machine. You take about 8 tons of raw material and 17 tons of water and let her process it for you, and you get 3 tons of salable product and enough left over to grow next year's crops. It seems to me that a production line method of handling all that tonnage would help take it off the back of the fellow who is trying to keep bread on his table by running a milk factory.

WIRING FOR INCREASED USE OF ELECTRICITY

A farm wiring system designed around electrified farming will be much simpler when the building design has been taken care of. We will need circuits, outlets, portable cords, and trolley connections, the material for which will probably be all ready for use, the methods and equipment having been tried and developed in other industries. With small automatic equipment, wire sizes might be small, but the circuits serving portable equipment might want to be entirely of "plug-in strip." Anyway, if there is a little ingenuity, imagination, and a very liberal portion of hard-boiled horse sense put on all these problems, we should get a crop of practical and workable uses and equipment that effectively make use of the electric method.

Can the complete electrification of farms contribute to larger farm income? Yes, it certainly can. With reduced production costs, together with increased quantity and quality, the net income will be larger; farm and farm home uses can contribute materially to better working and living conditions, so that farm people may have more things that they never had before. But if this is to be brought about, farmers, manufacturers, researchers, educators, and electric service companies will have to keep everlastingly alert while they keep plugging away at the job—plugging in all the proved devices and equipment, and plugging at the hard work that will develop and prove new ones.

Transport Wheels for Agricultural Machines

IX. Effective Radius and Slippage

By Eugene G. McKibben and J. Brownlee Davidson

FELLOW A.S.A.E. CHARTER A.S.A.E.

SUMMARY

1 The loaded radii and distances of forward travel per revolution were measured for all of the steel wheels and pneumatic tires used in the rolling resistance studies reported in the earlier articles of this series.

2 Effective radii and slippages were calculated from these data.

3 Slippage occurred in all tests on agricultural soils.

4 This slippage was approximately proportional to the square of the coefficient of rolling resistance.

UNDER many conditions the effective radius and slippage of a transport wheel may be of little interest. From the viewpoint of the agricultural engineer, however, a study of transport wheels would not be complete without evaluation of these factors. This is particularly true in view of the frequent use of transport wheels as driving wheels for accessory mechanisms.

Definitions. For the purpose of this article the "effective radius" of a transport wheel is defined as the forward travel during one revolution divided by 6.2832; the "loaded radius" as the height of the axle center when supporting a stationary load on a concrete road; and the "slippage" as the difference between the effective radius and the loaded radius, divided by the loaded radius. The use of the loaded radius on concrete as the basis for slippage is admittedly arbitrary but seemed the best solution in view of the difficulty of determining loaded radii for varying soil conditions.

Slippage. The effective radius and slippage of a transport wheel is determined by a large number of wheel and soil factors. In general, however, it may be stated that the effective radius will be greater than the loaded radius for any transport wheel operated on a friable (nonelastic in tension) medium. Thus the bottom of the wheel is not stationary with respect to the soil but is slipping forward. This proposition has been analyzed by the methods of theoretical mechanics in a previous publication[1] and is supported by the data presented in this article.

Test Methods. The loaded radii, as already defined, were determined for all the steel wheels and for all loads and inflation pressures of all pneumatic tires used in the rolling resistance investigations reported in the previous articles of this series. For each trial the forward travel per revolution of the test wheel was obtained by a special pencil on the dynamometer chart[1].

Individual Wheels. From these data the per cent slippage values shown for two steel wheels and two pneumatic tires in Fig. 1 were calculated. The values plotted on the graphs of this figure represent three loads and seventeen road and field conditions varying from a concrete road to loose tilled sand. These are the same tests as those shown

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The authors are, respectively, associate professor of agricultural engineering, and professor and head of the department of agricultural engineering, Iowa State College.

[1] McKibben, Eugene G. Some kinematic and dynamic studies of rigid transport wheels for agricultural equipment. Iowa Agr. Exp. Sta. Res. Bul. 231. March 1938.

TABLE 1. SLIPPAGE[a] IN PER CENT FOR TWENTY-THREE INDIVIDUAL WHEELS[b] ON FOUR ROAD AND FIELD[c] CONDITIONS AT TWO OR THREE DIFFERENT LOADS[d]

	500-lb load							1000-lb load						1500-lb load					
	Unloaded radius	Pressure, lb per sq in	Loaded radius, in[e]	Slippage, per cent Field[c]				Pressure, lb per sq in	Loaded radius in[e]	Slippage, per cent Field[c]				Pressure, lb per sq in	Loaded radius, in[e]	Slippage, per cent Field[e]			
Wheel	in			A	B	C	D			A	B	C	D			A	B	C	D
2.5x36	18.0	S[f]	18.0	0.0	1.1	20.6	22.8	S	18.0	0.0	1.7	23.0	25.0	S	18.0	0.0	2.2	24.4	28.9
4x24	12.0	S	12.0	0.0	1.7	40.0	41.7	S	12.0	0.0	2.5	50.0	68.4	S	12.0	0.8	2.5	—	—
4.00-18	13.2	20	12.5	0.8	2.4	25.6	30.4	44	12.5	0.8	4.0	—	—	—	—	—	—	—	—
4x36	18.0	S	18.0	0.6	1.7	20.6	22.8	S	18.0	0.6	2.2	17.2	34.5	S	18.0	0.6	—	—	—
4.00-30	19.2	16	18.4	0.5	0.5	17.9	15.8	36	18.4	0.0	1.1	20.6	14.7	—	—	—	—	—	—
4.00-36	22.2	16	21.1	1.0	1.4	15.6	14.2	36	21.3	0.0	0.9	16.9	18.8	—	—	—	—	—	—
5.00-16	12.8	16	11.8	2.6	2.5	28.0	28.8	32	11.7	2.6	4.3	32.5	41.0	—	—	—	—	—	—
6x28	14.0	S	14.0	0.7	2.1	23.6	25.7	S	14.0	0.7	3.6	32.8	51.4	S	14.0	0.7	2.1	38.6	62.9
6.00-16	13.8	16	13.0	1.5	0.8	22.3	21.5	20	12.6	3.2	4.8	27.8	34.1	40	12.6	4.0	5.6	34.1	44.4
6.00-16[g]	14.8	20	13.0	11.5	20.8	31.9	29.2	30	12.9	10.8	17.1	38.8	45.7	—	—	—	—	—	—
7.50-10	12.5	16	11.6	1.7	3.4	25.0	28.4	20	11.2	4.5	5.4	40.3	45.6	32	11.3	3.5	4.8	50.4	46.0
7.50-16	15.2	16	14.6	0.6	2.0	21.9	14.4	16	13.9	2.1	5.0	24.5	28.1	20	13.6	3.7	4.4	30.2	36.1
7.50-28	22.0	16	21.2	0.0	0.9	10.4	8.5	16	20.6	1.4	1.9	14.6	17.5	16	20.2	1.5	2.0	15.4	15.8
8x48[h]	24.0	S	24.0	0.0	0.8	10.0	9.6	S	24.0	-0.4	1.2	15.0	15.4	S	24.0	-0.8	1.2	15.8	25.4
7.50-36	25.8	16	25.2	-0.8	0.0	7.5	8.7	16	24.1	1.7	2.5	14.9	14.5	16	24.1	0.8	0.4	13.3	11.2
9.00-10	13.7	16	12.8	2.3	2.3	18.8	25.0	20	12.6	2.4	2.2	30.2	38.9	32	12.5	3.2	5.6	32.8	48.8
9.00-16	16.4	16	15.8	0.6	1.3	—	12.6	16	15.2	2.0	3.3	22.9	27.0	16	14.7	3.4	4.8	26.5	28.6
9.00-24	21.4	16	20.8	0.5	1.4	9.1	6.2	16	20.2	1.0	4.5	14.3	15.6	16	19.8	1.5	2.0	14.6	18.7
	1000-lb load							1500-lb load						2000-lb load					
9.00-40	29.4	16	28.3	0.4	1.4	9.5	11.0	16	27.9	0.7	0.7	9.7	12.5	16	27.5	0.7	1.8	11.3	13.8
11.25-24	23.3	16	22.1	1.4	2.7	12.6	5.0	16	21.6	2.3	2.8	13.9	16.2	16	21.2	3.3	4.2	17.0	18.9
11.25-36	29.3	16	28.2	0.0	1.1	8.9	11.0	16	27.8	0.0	0.7	9.7	12.9	16	27.4	-0.4	1.8	12.8	13.1
14x60[h]	30.0	S	30.0	0.0	1.0	8.0	7.7	S	30.0	0.0	0.7	8.7	13.0	S	30.0	-0.3	1.0	11.0	14.3
12.75-32	28.2	16	27.2	2.2	1.5	9.2	9.6	16	26.6	1.5	2.6	12.8	14.3	16	25.7	3.9	5.4	14.8	17.5

[a] Calculated on the basis of stationary loaded radius on concrete.

[b] Rolling resistance data for the same wheels and operating conditions were given in Table 3 of the second article of this series (AGRICULTURAL ENGINEERING 20:471, December 1939).

[c] Concrete road, bluegrass pasture, tilled loam, and loose sand, respectively. These road and field conditions were also described in detail in the article just cited.

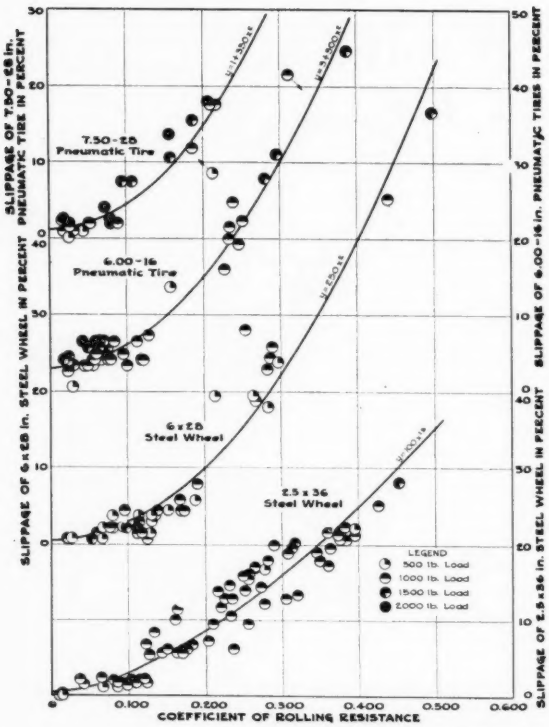
[d] Because of limitations of testing equipment the largest loads used were only one third of the recommended capacities of the larger tires.

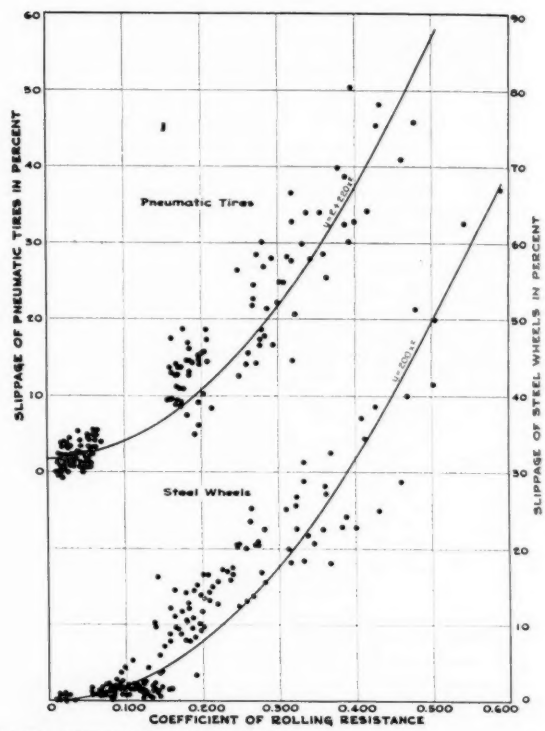
[e] When supporting load on concrete road.

[f] Steel wheels.

[g] Skid-ring tractor tire.

[h] Tests of the 48 and 60-in steel wheels on concrete were made with 4-in rim width.


SLIPPAGE OF 7.50-28 in. STEEL WHEEL IN PERCENT
SLIPPAGE OF 6.00-16 in. PNEUMATIC TIRE IN PERCENT
SLIPPAGE OF 6 x 28 in. STEEL WHEEL IN PERCENT
SLIPPAGE OF 2.5 x 36 in. STEEL WHEEL IN PERCENT
7.50-28 Pneumatic Tire
6.00-16 Pneumatic Tire
6 x 28 Steel Wheel
2.5 x 36 Steel Wheel
LEGEND
500 lb. Load
1000 lb. Load
1500 lb. Load
2000 lb. Load
COEFFICIENT OF ROLLING RESISTANCE


SLIPPAGE OF PNEUMATIC TIRES IN PERCENT
SLIPPAGE OF STEEL WHEELS IN PERCENT
Pneumatic Tires
Steel Wheels
COEFFICIENT OF ROLLING RESISTANCE

RELATION BETWEEN COEFFICIENT OF ROLLING RESISTANCE AND SLIPPAGE

Fig. 1 (Left) Relation between coefficient of rolling resistance and slippage for two steel and two pneumatic transport wheels at three loads on seventeen road and field conditions varying from concrete to loose tilled sand. Each point represents the mean of three non-consecutive 50-ft tests. The standard error of these mean coefficients of rolling resistances varied from 0.002 for concrete to 0.04 for tilled loam and the corresponding standard errors for per cent slippage were 0.28 and 0.48, respectively. Fig. 2 (Right) Relation between coefficient of rolling resistance and slippage for sixteen pneumatic tires varying from 4.00-18 to 12.75-32 in and fifteen steel wheels varying from 2.5x24 to 14x60 in at three loads on road and field conditions varying from concrete to loose tilled sand

TABLE 2. COEFFICIENTS OF ROLLING RESISTANCE[a] AND PER CENT SLIPPAGE[b] OF 6.00-16 AND 7.50-28-IN IMPLEMENT TIRES AT FIVE INFLATION PRESSURES AND THREE LOADS ON FOUR ROAD AND FIELD CONDITIONS

				Road and field conditions[c]							
				A-Concrete		B-Bluegrass		C-Tilled loam		D-Loose sand	
Tire	Load, lb	Pressure, lb per sq in	Loaded radius[d] in	Coef. R.R.[a]	Slippage,[b] per cent	Coef. R.R.[a]	Slippage,[b] per cent	Coef. R.R.[a]	Slippage,[b] per cent	Coef. R.R.[a]	Slippage,[b] per cent
6:00-16 4-ply	500	10	12.4	.036	4.8	.058	6.4	.278	23.6	.260	24.2
		15	13.0	.034	1.5	.056	3.9	.300	22.3	.286	23.1
		20	13.1	.032	2.3	.058	3.8	.320	19.8	.308	24.4
		30	13.2	.028	2.3	.060	3.0	.330	21.2	.312	25.0
		40	13.3	.026	2.3	.062	3.8	.328	20.3	.326	24.8
	1000	10	11.3	.040	10.6	.062	9.7	.239	30.1	.226	31.9
		15	12.2	.030	4.1	.057	5.7	.297	30.4	.281	31.2
		20	12.6	.027	3.2	.060	3.2	.319	27.8	.338	34.9
		30	12.8	.022	3.1	.064	4.7	.345	33.6	.397	41.5
		40	12.9	.023	3.9	.063	4.6	.354	34.9	.410	42.6
	1500	10	10.2	.064	21.6	.065	17.6	.225	34.3	.241	39.2
		15	11.5	.032	8.7	.055	7.8	.261	31.3	.267	31.3
		20	11.9	.027	6.7	.055	5.9	.289	28.5	.319	34.5
		30	12.5	.023	4.0	.056	4.8	.335	34.4	.389	43.2
		40	12.6	.021	4.0	.060	5.5	.355	31.7	.417	47.5
7.50-28 4-ply	1000	10	20.2	.028	4.4	.053	1.0	.182	10.8	.179	14.7
		15	20.5	.023	3.4	.055	1.5	.208	13.6	.207	17.1
		20	20.8	.022	2.9	.057	1.4	.218	13.5	.211	17.8
		30	21.1	.016	2.4	.060	1.0	.223	11.9	.235	18.1
		40	21.2	.016	2.8	.054	1.4	.231	11.8	.238	17.4
	1500	10	19.5	.033	5.6	.054	2.6	.177	16.4	.173	18.5
		15	20.1	.026	4.0	.052	1.5	.197	13.4	.205	17.4
		20	20.6	.023	1.9	.053	0.5	.219	13.6	.232	19.9
		30	20.8	.019	2.4	.055	1.4	.239	15.4	.263	23.1
		40	21.0	.017	1.9	.057	1.0	.253	11.9	.272	26.0
	2000	10	19.2	.036	5.7	.054	2.6	.153	13.0	.173	19.3
		15	19.8	.030	3.5	.045	2.0	.168	13.6	.210	22.7
		20	20.3	.023	1.0	.045	1.5	.186	13.8	.247	26.6
		30	20.6	.021	2.9	.049	1.9	.202	16.1	.281	29.1
		40	20.8	.020	2.4	.053	1.4	.211	16.4	.291	29.8

[a]Rolling resistance divided by the load.

[b]Calculated on the basis of the loaded radius on concrete.

[c]These road and field conditions are described in detail in Table 2 and Figs. 2 to 5 of the second article of this series (II. Rolling Resistance of Individual Wheels. AGRICULTURAL ENGINEERING 20:469-473, December 1939).

[d]Measured when supporting load on concrete road. The unloaded radii of these two tires were 13.9 and 22.0 in, respectively.

in Fig. 3 of Article VIII of this series[2]. The curves shown were selected arbitrarily by the authors because of their simple mathematical form combined with a reasonably good graphical fit.

Slippage Data. The per cent slippage values listed in Tables 1 and 2 were calculated from the loaded radius and travel distance measurements previously mentioned. Values of the effective radii are not shown because these tables are already very large. The effective radii may be readily calculated, however, from the slippage percentages and loaded radii. Conditions represented by Tables 1 and 2 correspond to those of Table 3 of Article II[3] and Table 1 of Article III[4] of this series.

The data of Table 1 were used to plot the two graphs of Fig. 2, one for steel wheels and the other for pneumatic tires. The graph for steel wheels also includes data[1] taken in 1936. Thus the points shown in Fig. 2 represent sixteen pneumatic tires vary- *(Continued on page 280)*

[2]AGRICULTURAL ENGINEERING 21:231-234, June 1940.

[3]AGRICULTURAL ENGINEERING 20:469-473, December 1939.

[4]AGRICULTURAL ENGINEERING 21:25-26, January 1940.

Field Studies with Dual Tractor Tires

By C. W. Smith
MEMBER A.S.A.E.

THIS paper presents some results of work done to compare dual tractor tires with single tires while using a general-purpose tractor on lister ridges, on wet stubble ground, and on plowed ground.

For all work the rear static weight of the tractor was kept constant at 4090 lb. This weight included the weight of the tractor operator, and also the weight of the burette operator while fuel consumption data were being taken. The tractor was driven in second gear and used tractor fuel.

Lister Ridges. A large percentage of the corn acreage in Nebraska is listed. The first two or three cultivations require the tractor wheels to ride the lister ridges. There is no uniformity in the depth of listing. Some farmers feel that the corn does better when the listing is deep; others feel that the corn does just as well, if not better, when the listing is shallow. With conditions differing widely from one locality to another, both are right.

Steel wheels with spade lugs ride any lister ridge fairly satisfactorily. Any type of wheel equipment can be made to ride low flat ridges. Single pneumatic tires have not given general satisfaction for cultivating listed corn. Dual pneumatics have been proposed as a solution to the problem. In preparing to compare the action of single tires and dual tires on lister ridges an overrunning clutch was mounted on the steering column of the tractor and a revolution counter was driven through the clutch. Fig. 1 is a picture of this equipment as mounted on the steering column of the tractor. When the wheel was turned in one direction it turned the counter; when turned in the opposite direction it did not turn the counter. Counter readings under various conditions gave a comparison of the steering efforts required. A long, level field with uniform soil conditions on the Hoffman farm northeast of Lincoln, Nebraska, was used. Two rows of stakes were set up through this field parallel with the lister rows. The stake rows were 50 ft apart, and the stakes were set 100 ft apart in the rows. Tests were run on each side of the double row of stakes, data being taken for each alternate 100 ft. Fig. 2 shows the equipment as used on the lister ridges. The testing equipment was never driven on ridges a second time. Comparable drawbar loads were imposed on all wheel equipment on adjacent tracks between the same pairs of stakes.

The lister ridges were of medium height. The soil was in splendid condition to be worked. Three drivewheel spacings on the 9.00x36 single tires were tried, 84, 76, and 68 in. The ridges were 42 in apart. It was the judgment of all five men assisting with these tests that, if there was any preferable wheel spacing, in this case it was 84 in. The single tires were not satisfactory for this work under any condition tried. The plan had been to try various front-wheel equipment and front-wheel spacings, but it was so obvious that the rear end of the tractor slipped off the ridges in most instances while the front wheels were still riding on top quite satisfactorily, that no changes were made on the front wheels. It is obvious, however, that if the rear tires were riding the ridges satisfactorily, steering could be made still easier by spreading the front tires.

The 9.00x36 and the 7.00x40 dual tires were each run at two inflation pressures, 12 and 16 lb, and it had been in the plan to run the 9.00x36 singles at these two inflation pressures, but the action of the singles was so unsatisfactory that no attempt was made to run them at a second inflation pressure. The inflation pressure used on the singles was 12 lb. A significant difference in the performance of the duals could neither be detected in the way they handled, nor in a general examination of the data taken using different inflation pressures. Since all data could not be presented, it seemed advisable to use one inflation pressure as far as possible, and 16 lb was arbitrarily chosen for this purpose. Figs. 3 and 4 show graphically the results. Fig. 3 shows results obtained while traveling north and on the west side of the rows of stakes; Fig. 4 shows results from the east side of the stakes and traveling south. The singles required much more steering effort while pulling less pounds than any of the duals. No significant difference between duals was apparent.

Wet Stubble Ground. Comparative draft, travel reduction, and horsepower tests were made with duals and singles on a wet stubble field on the Hoffman farm. This particular field and time was chosen to secure unfavorable footing or traction for a rubber-tired tractor. The tractor's behavior under these circumstances would simulate its action in an

Presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., December 5, 1939. The author is professor of agricultural engineering at the University of Nebraska.

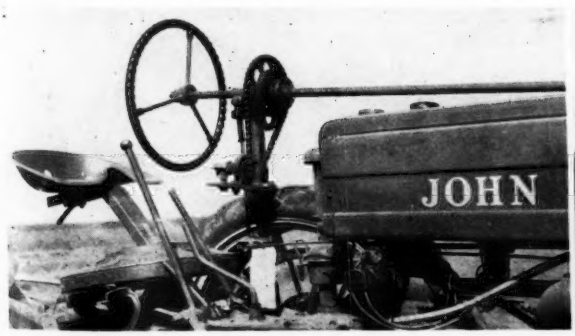
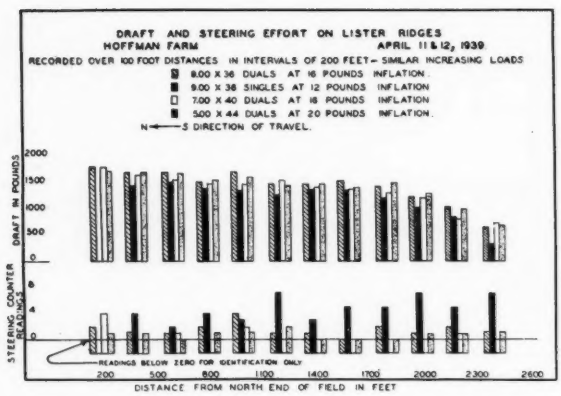
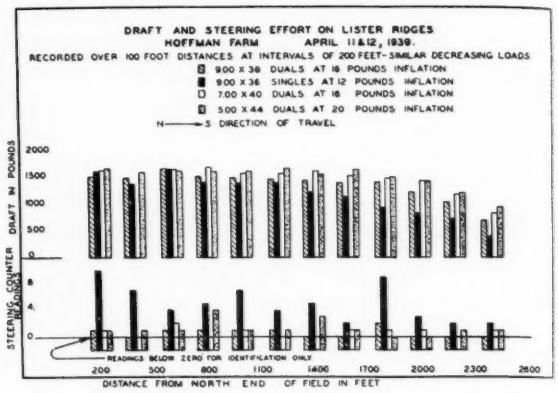


Fig. 1 (Left) Overrunning clutch mounted on the steering column of a tractor through which a revolution counter is driven for the purpose of comparing steering effort. Fig. 2 (Right) Equipment as used on lister ridges for the purpose of getting draft, travel reduction, and steering-effort data


DRAFT AND STEERING EFFORT ON LISTER RIDGES
HOFFMAN FARM APRIL 11 & 12, 1939
RECORDED OVER 100 FOOT DISTANCES IN INTERVALS OF 200 FEET- SIMILAR INCREASING LOADS
8.00 X 36 DUALS AT 16 POUNDS INFLATION.
9.00 X 36 SINGLES AT 12 POUNDS INFLATION.
7.00 X 40 DUALS AT 16 POUNDS INFLATION.
5.00 X 44 DUALS AT 20 POUNDS INFLATION.
N S DIRECTION OF TRAVEL.
DRAFT IN POUNDS
STEERING COUNTER READINGS
READINGS BELOW ZERO FOR IDENTIFICATION ONLY
DISTANCE FROM NORTH END OF FIELD IN FEET


DRAFT AND STEERING EFFORT ON LISTER RIDGES
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RECORDED OVER 100 FOOT DISTANCES AT INTERVALS OF 200 FEET- SIMILAR DECREASING LOADS
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N S DIRECTION OF TRAVEL
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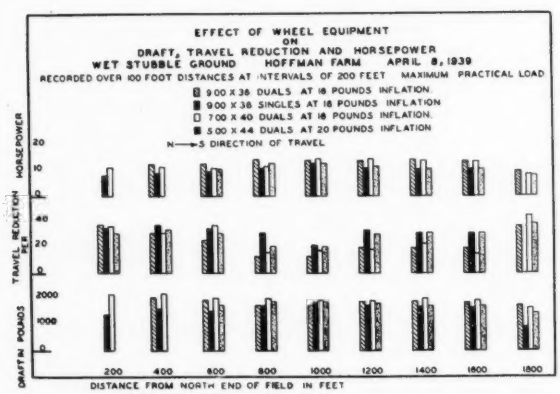
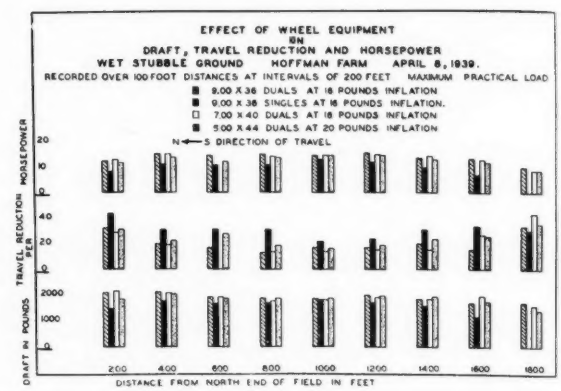
DISTANCE FROM NORTH END OF FIELD IN FEET


EFFECT OF WHEEL EQUIPMENT
ON
DRAFT, TRAVEL REDUCTION AND HORSEPOWER
WET STUBBLE GROUND HOFFMAN FARM APRIL 8, 1939
RECORDED OVER 100 FOOT DISTANCES AT INTERVALS OF 200 FEET MAXIMUM PRACTICAL LOAD
9.00 X 36 DUALS AT 16 POUNDS INFLATION.
9.00 X 36 SINGLES AT 16 POUNDS INFLATION
7.00 X 40 DUALS AT 16 POUNDS INFLATION.
5.00 X 44 DUALS AT 20 POUNDS INFLATION
N S DIRECTION OF TRAVEL
TRAVEL REDUCTION PER HORSEPOWER
DRAFT IN POUNDS
DISTANCE FROM NORTH END OF FIELD IN FEET


EFFECT OF WHEEL EQUIPMENT
ON
DRAFT, TRAVEL REDUCTION AND HORSEPOWER
WET STUBBLE GROUND HOFFMAN FARM APRIL 8, 1939.
RECORDED OVER 100 FOOT DISTANCES AT INTERVALS OF 200 FEET MAXIMUM PRACTICAL LOAD
9.00 X 36 DUALS AT 16 POUNDS INFLATION
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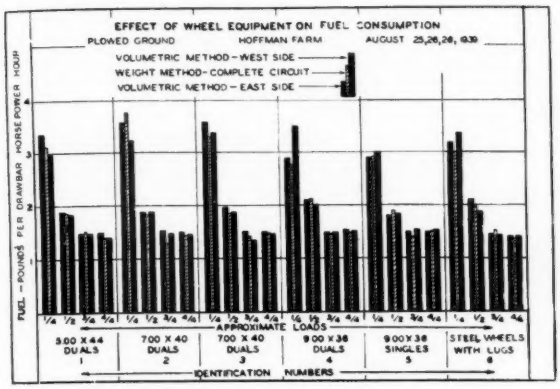
7.00 X 40 DUALS AT 16 POUNDS INFLATION
5.00 X 44 DUALS AT 20 POUNDS INFLATION
N S DIRECTION OF TRAVEL
TRAVEL REDUCTION PER HORSEPOWER
DRAFT IN POUNDS
DISTANCE FROM NORTH END OF FIELD IN FEET

Fig. 3 (Upper left) Graphical presentation of draft and steering-effort data taken on lister ridges with dual and single pneumatic tires, while traveling north. Fig. 4 (Upper right) Graphical presentation of draft and steering-effort data taken on lister ridges with dual and single pneumatic tires, while traveling south. Fig. 6 (Lower left) Graphical presentation of data showing the effect of wheel equipment on draft, travel reduction, and horsepower, on wet stubble ground (too wet for usual farm operations). Nine sets of data were taken while traveling south and without interrupting the tractor's forward progress in a straight line. Fig. 7 (Lower right) Graphical presentation of data showing the effect of wheel equipment on draft, travel reduction, and horsepower, on wet stubble ground. Nine sets of data were taken while traveling north and without interrupting the tractor's forward progress in a straight line

emergency. The stubble on this field, left from combining, stood 25 in high and had at its base a dense undergrowth from 3 to 4 in thick. The ground was wet and this dense undergrowth prevented evaporation. At any time while testing on this stubble field the undergrowth could be pushed aside and a mud ball made from the top soil. While the field appeared perfectly level the ends of our test plot had soaked up more water than the center. The center of the test plot gave the best traction and the least travel reduction. An attempt was made to impose a fairly heavy load on the tractor at all times, lessening it only to keep from getting stuck. In spite of caution, it stuck once on the south end of the field. Only one inflation pressure, namely, 20 lb, was used with the 5.00x44 duals; but two inflation pressures were used with the 9.00x36 singles and the 7.00x40 duals, 12 and 16 lb; and three pressures 10, 12, and 16 lb were used with the 9.00x36 duals. Fig. 5 shows a wheel-sliding tool developed for this work. Figs. 6 and 7 show some of the results. The single tires, with less draft, show more travel reduction and less horsepower than any dual tire. The 5.00x44 duals had a little more difficulty under these circumstances than the larger duals. Little or no difference can be seen from the data in the performance of the 7.00x40 duals and the 9.00x36 duals under these circumstances. Fresh tracks were being made at all times while data were being taken.

Dual Tires and Tractor Fuel Consumption. Volumetric fuel-measuring equipment was built and installed on a general-purpose tractor which made it possible to take fuel consumption data on the tractor while it was doing field work, without interrupting its forward progress or load. A level field on the Hoffman farm was used for this purpose. It had been plowed and harrowed following wheat harvest and was standing idle until the time for reseeding to wheat. It had been standing long enough previous to these tests to

FIG. 5 A SPECIAL TOOL DESIGNED TO ASSIST IN SLIPPING WHEELS ON SPLINED AXLE SHAFTS


EFFECT OF WHEEL EQUIPMENT ON FUEL CONSUMPTION
PLOWED GROUND HOFFMAN FARM AUGUST 25,26,28, 1939
VOLUMETRIC METHOD - WEST SIDE
WEIGHT METHOD - COMPLETE CIRCUIT
VOLUMETRIC METHOD - EAST SIDE
FUEL - POUNDS PER DRAWBAR HORSE POWER HOUR
APPROXIMATE LOADS
5.00 X 44 DUALS 1
700 X 40 DUALS 2
700 X 40 DUALS 3
9.00 X 36 DUALS 4
9.00 X 36 SINGLES 5
STEEL WHEELS WITH LUGS 6
IDENTIFICATION NUMBERS

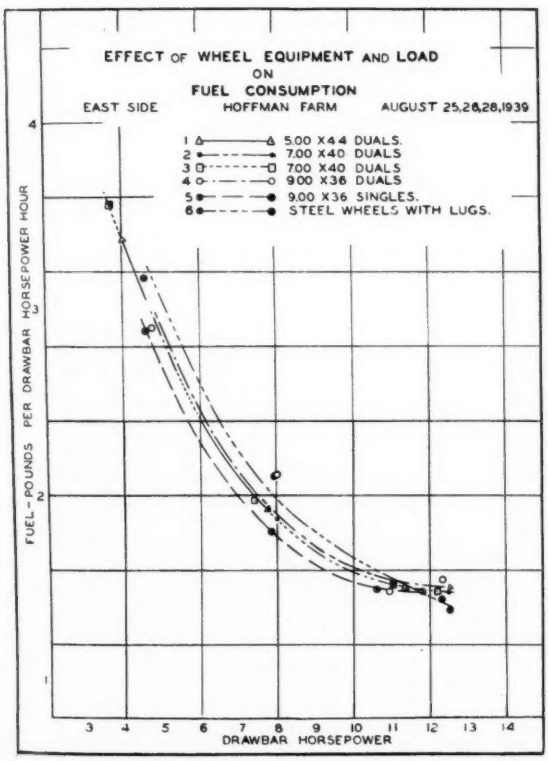
FUEL CONSUMPTION WITH VARIOUS WHEEL EQUIPMENT
VOLUMETRIC AND WEIGHT METHODS

HOFFMAN FARM AUGUST 25,26&28,1939

FIELD POSITION	IDENTIFICATION NUMBER	DESCRIPTION	¼ LOAD SPEED MI. PER HR.	¼ LOAD DRAFT POUNDS	¼ LOAD TRACTION REDUCTION PERCENTAGE	¼ LOAD HORSE POWER	¼ LOAD FUEL LB./H.P./HR.	½ LOAD SPEED MI. PER HR.	½ LOAD DRAFT POUNDS	½ LOAD TRACTION REDUCTION PERCENTAGE	½ LOAD HORSE POWER	½ LOAD FUEL LB./H.P./HR.	¾ LOAD SPEED MI. PER HR.	¾ LOAD DRAFT POUNDS	¾ LOAD TRACTION REDUCTION PERCENTAGE	¾ LOAD HORSE POWER	¾ LOAD FUEL LB./H.P./HR.	FULL LOAD SPEED MI. PER HR.	FULL LOAD DRAFT POUNDS	FULL LOAD TRACTION REDUCTION PERCENTAGE	FULL LOAD HORSE POWER	FULL LOAD FUEL LB./H.P./HR.
EAST	1	5.00 X 44 DUALS	3.43	443	3.09	4.04	3.37	3.28	883	8.02	7.75	1.92	3.00	1423	12.58	10.39	1.56	2.66	1730	19.91	12.56	1.81
	2	7.00 X 40 DUALS	3.42	407	2.80	3.72	2.57	3.28	825	6.73	8.01	1.87	3.01	1317	12.36	11.08	1.32	2.78	1605	17.62	12.50	1.40
	3	7.00 X 40 DUALS	3.36	412	2.91	3.71	3.56	3.23	883	6.75	7.42	1.97	2.89	1283	12.13	11.02	1.52	2.78	1660	19.01	12.20	1.63
	4	9.00 X 36 DUALS	3.37	528	4.11	4.79	2.06	3.24	820	6.68	9.04	2.11	2.92	1403	12.81	10.98	1.48	2.81	1715	21.53	12.37	1.55
	5	9.00 X 36 SINGLES	3.34	518	4.01	4.81	2.05	3.18	837	7.01	7.98	1.91	2.93	1390	13.20	10.63	1.48	2.85	1678	21.35	11.82	1.42
	6	STEEL WHEELS WITH LUGS	3.48	486	3.20	4.60	3.17	3.34	864	7.05	7.98	2.10	3.18	1457	9.00	12.24	1.42	2.79	1820	11.38	12.58	1.35
WEST	1	5.00 X 44 DUALS	3.48	481	3.11	4.54	2.99	3.30	896	7.81	7.81	1.86	3.01	1431	12.20	11.46	1.50	2.72	1850	18.34	13.41	1.42
	2	7.00 X 40 DUALS	3.48	454	2.17	4.16	3.21	3.26	864	8.10	7.62	1.86	2.99	1412	12.71	11.26	1.48	2.75	1700	18.46	12.46	1.48
	3	7.00 X 40 DUALS	3.42	444	1.86	4.05	3.38	3.29	894	8.96	7.78	1.87	3.00	1387	11.52	12.88	1.33	2.75	1895	17.71	12.46	1.41
	4	9.00 X 36 DUALS	3.42	418	3.07	3.76	3.80	3.28	845	5.99	8.25	2.01	2.98	1395	11.82	11.01	1.50	2.85	1740	20.84	12.27	1.54
	5	9.00 X 36 SINGLES	3.37	488	3.35	4.38	3.00	3.19	922	8.06	7.75	1.93	2.84	1398	13.17	10.34	1.55	2.88	1874	23.05	11.50	1.54
	6	STEEL WHEELS WITH LUGS	3.34	445	1.81	4.20	3.35	3.27	868	4.94	8.08	1.88	3.14	1503	8.32	12.57	1.43	2.73	1889	10.21	12.12	1.40
CIRCUIT	1	5.00 X 44 DUALS				4.29	3.13				7.81	1.88				11.46	1.53				12.98	1.41
	2	7.00 X 40 DUALS				3.95	3.74				8.08	1.79				11.17	1.28				12.48	1.43
	3	7.00 X 40 DUALS				3.88	3.28				7.80	1.88				11.85	1.42				12.33	1.48
	4	9.00 X 36 DUALS				4.29	2.75				8.25	2.14				10.98	1.48				12.32	1.48
	5	9.00 X 36 SINGLES				4.49	2.01				7.92	1.91				10.81	1.41				11.66	1.52
	6	STEEL WHEELS WITH LUGS				4.26	2.98				8.22	1.99				12.45	1.22				12.34	1.35

Fig. 8 (Left) Graphical presentation of data showing the effect of wheel equipment on fuel consumption. Among the many things of interest to be seen in this chart is the fact that two sets of 7.00x40 duals of different makes made almost identical records. Table (Right) Data taken on plowed ground with a general-purpose tractor using four sets of dual pneumatic tires, one set of single pneumatics and one pair of narrow channel steel wheels with spade lugs. The effective circumferences of all wheel equipment were very nearly the same and were determined by driving the tractor without load over the same soil conditions as were used for the tests. Some decimals have been omitted from the tabulations which were used in computations

reach almost a static condition with respect to moisture content and tilth. The soil was in splendid condition for test work. Tractor fuel, A.P.I. 39.4, was used. The fuel bulb had a capacity of 595 cc. It was estimated that this would be sufficient to carry the tractor 1400 ft at one-fourth load, 1200 ft at one-half load, 1000 ft at three-fourths load, and 800 ft at full load. The field plan made it possible to use these distances for the various loads. Volumetric data were taken on both sides of the stakes and fuel and time data for the complete circuit by weight. It was not possible to keep the load adjusted as accurately around the ends as along the sides. The average of the drawbar pull on the two sides was assumed to have been the draft for the entire circuit and was used for weight


EFFECT OF WHEEL EQUIPMENT AND LOAD ON FUEL CONSUMPTION
EAST SIDE HOFFMAN FARM AUGUST 25,26,28,1939
1 5.00 X 44 DUALS.
2 7.00 X 40 DUALS
3 7.00 X 40 DUALS
4 9.00 X 36 DUALS
5 9.00 X 36 SINGLES.
6 STEEL WHEELS WITH LUGS.
FUEL - POUNDS PER DRAWBAR HORSEPOWER HOUR
DRAWBAR HORSEPOWER

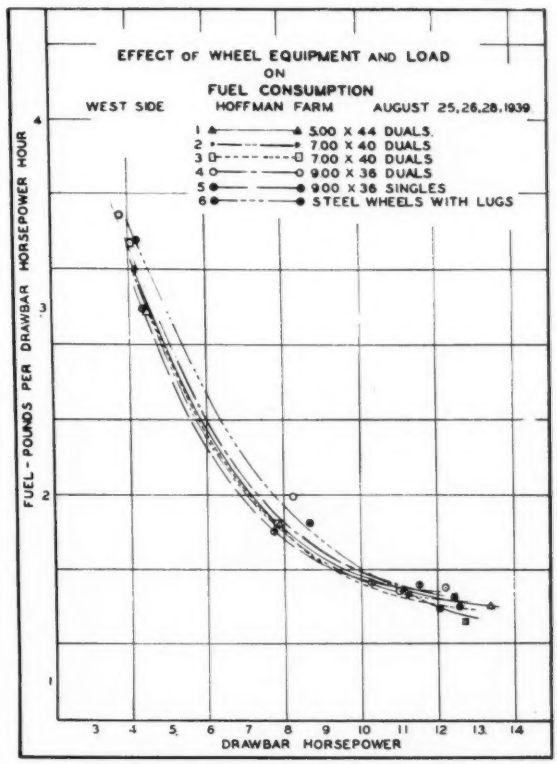
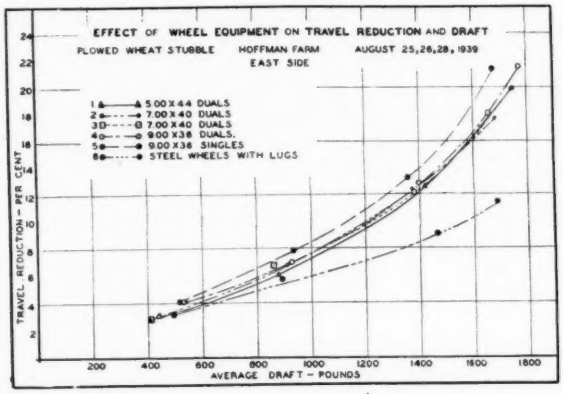

EFFECT OF WHEEL EQUIPMENT AND LOAD ON FUEL CONSUMPTION
WEST SIDE HOFFMAN FARM AUGUST 25,26,28,1939
1 5.00 X 44 DUALS.
2 7.00 X 40 DUALS
3 7.00 X 40 DUALS
4 9.00 X 36 DUALS
5 9.00 X 36 SINGLES
6 STEEL WHEELS WITH LUGS
FUEL - POUNDS PER DRAWBAR HORSEPOWER HOUR
DRAWBAR HORSEPOWER

Fig. 9 (Left) Fuel consumption data from the east side of the stakes plotted against drawbar horsepower. The curves for the four sets of duals came so nearly falling upon one another that only two curves are drawn in for them. One of these is for the 9.00x36 duals. The other is a composite curve showing the other three sets of duals. Fig. 10 (Right) Fuel consumption data from the west side of the stakes plotted against drawbar horsepower. Like Fig. 9, the steel shows the highest fuel consumption on all except the heaviest loads, and the single pneumatics, the least fuel consumption except on heaviest loads. The duals show no apparent significant differences


EFFECT OF WHEEL EQUIPMENT ON TRAVEL REDUCTION AND DRAFT
PLOWED WHEAT STUBBLE HOFFMAN FARM AUGUST 25,26,28, 1939
EAST SIDE
1 5.00 X 44 DUALS
2 7.00 X 40 DUALS
3 7.00 X 40 DUALS
4 9.00 X 36 DUALS.
5 9.00 X 36 SINGLES
6 STEEL WHEELS WITH LUGS
TRAVEL REDUCTION - PER CENT
AVERAGE DRAFT - POUNDS

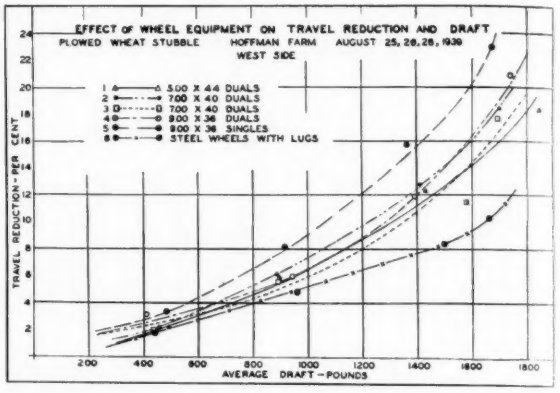

EFFECT OF WHEEL EQUIPMENT ON TRAVEL REDUCTION AND DRAFT
PLOWED WHEAT STUBBLE HOFFMAN FARM AUGUST 25, 26, 28, 1939
WEST SIDE
1 5.00 X 44 DUALS
2 7.00 X 40 DUALS
3 7.00 X 40 DUALS
4 8.00 X 36 DUALS
5 8.00 X 36 SINGLES
6 STEEL WHEELS WITH LUGS
TRAVEL REDUCTION - PER CENT
AVERAGE DRAFT - POUNDS

Fig. 11 (Lower left) Graphical presentation of the effect of wheel equipment on travel reduction and draft from data taken on the east side of the stakes. The similarity of the dual tire curves is striking. Fig. 12 (Lower right) Graphical presentation of the effect of wheel equipment on travel reduction and draft from data taken on the west side of the stakes

computations. Therefore, the volumetric data are the better and should get the emphasis. The weight data should be considered only as a check.

Fig. 8 shows fuel consumption in pounds per drawbar-horsepower-hour plotted against approximate loads. Preliminary runs were made to determine the maximum draft which could be secured without pulling the engine speed below rated speed, and without excessive travel reduction. This was taken as full load. Three values are given at each load. The solid left-hand bar was secured by the volumetric method on the east side of the stakes. The solid bar on the right-hand side was secured by the same method on the west side of the stakes. The center cross-hatched bar was secured by weighing the fuel used for the entire circuit, and, as has been said before, is not to be given the same consideration as the volumetric method data. The channel steel wheels with spade lugs were included as of general interest.

Figs. 9 and 10 show fuel consumption plotted against horsepower. From Fig. 10 the following data can be secured:

	Horsepower	Pounds fuel per drawbar-horsepower-hour
9.00x36 singles	7	1.95
Steel wheels	7	2.20

The steel-wheeled tractor used 12.8 per cent more fuel than the rubber-tired tractor at this load. There was less difference in fuel consumption between the duals and the steel wheels than between the singles and the steel. Above 10 drawbar horsepower there was no appreciable difference in fuel consumption with reference to the various wheels tried. Speeds and loads were not planned to show the advantages of rubber over steel. That rubber does have many advantages over steel is widely known and accepted. The plowing averaged between 5 and 6 in deep. The plowed ground was mellow and the plow sole dry and hard, which may have been somewhat favorable to the steel.

Figs. 11 and 12 show travel reduction versus draft. The steel wheels showed the least travel reduction and the single tires the most. There is insufficient data to classify the duals with any reasonable degree of certainty. It is apparent that differences in performance are small. The table gives data on fuel consumption.

CONCLUSIONS

1 It is difficult to make single pneumatic tires ride lister ridges. It can be done by throttling the tractor and pulling little or nothing.

2 Dual tires of any size, spaced $3\frac{1}{2}$ to $4\frac{1}{2}$ in apart on the rim, ride lister ridges satisfactorily.

3 Dual tires gave better traction on a wet stubble field than single tires, and can be expected to negotiate wet field spots better than single tires.

4 Dual tires had less travel reduction in plowed ground than single tires. In other words, they slipped less and gave better traction.

5 Dual tires showed a higher fuel consumption, in pounds per drawbar-horsepower-hour, than did the single tires. The difference was small and tends to discourage the idea of lessening fuel consumption and thereby tractor operating costs by the use of dual tires.

6 Dual tires may have the capacity to carry more added weight than single tires. The traction will increase in proportion to the increase in weight on the tires, until limited by engine horsepower.

AUTHOR'S NOTE: The cooperation of the Omaha branch of the John Deere Plow Company, the U. S. Rubber Company, and the Firestone Tire and Rubber Company is gratefully acknowledged.

Transport Wheels for Agricultural Machines

(Continued from page 276)

ing from 4.00-18 to 12.75-32 in and fifteen steel wheels varying from 2.5x24 to 14x60 in with both groups operated at three loads on road and field conditions varying from concrete to loose tilled sand.

Slippage and Coefficient of Rolling Resistance. The curves shown in Fig. 2 were selected arbitrarily the same as those of Fig. 1. A better fit could have been obtained by using a fractional exponent especially for the pneumatic tires. However, because in any case the equations would be empirical, the greater simplicity of an integral exponent seemed sufficient justification for this selection.

All the data obtained indicate a close relationship between the slippage and the coefficient of rolling resistance. Apparently those factors which determine the rolling resistance influence slippage in such a way as to cause the slippage to vary approximately as the square of the coefficient of rolling resistance.

The data of Tables 1 and 2 also indicate that with pneumatic tires a relatively higher slippage for a given rolling resistance may be expected when a large load is carried, when high inflation pressure is used on sand, or when a low inflation pressure is used on a hard surface like concrete.

A Method of Studying Soil Packing by Tractors

By I. F. Reed
MEMBER A.S.A.E.

SOIL packing produced by tractor wheels or tracks has been a topic of discussion since the advent of the tractor, and nearly every new type of wheel tread and track developed has been the subject of various claims of greater traction with less packing. Most of these claims have been unchallenged, as no satisfactory and easily applied method had been developed for measuring the relative compaction of the soil. The methods of determining the volume weights for layers of soil under the track, of the soil fixation used by Misenko[1]* and of driving piles used by Heath[2] should give accurate data, but all are slow and laborious. Culpin[3] tried shooting lead bullets into the soil. One recently developed device is designed to measure the penetration of a tapered rod when dropped from a predetermined height, and other units have been designed to push a probe into the soil with a fixed force. All of these methods use the depth of penetration as an index of compactness and are apparently unduly affected by hard layers in the soil. They give a composite value to the depth of penetration, but they do not indicate the condition that might go to make up this result, and they give no indication of conditions below. Culpin[3] developed an apparatus for forcing a probe into the soil at a nearly constant rate to any desired depth. The probe is forced down by calibrated springs whose deflections are recorded on a strip chart, thus giving an indicator type chart for each test. This unit is light in weight, easily operated and produces very satisfactory measurements, but has the disadvantage that the movement of the probe is retarded by the amount the springs are extended. This may cause considerable variation in the speed of penetration when hard or soft layers are encountered.

The soil resistance recorder shown in Fig. 1 was developed at the U.S.D.A. Tillage Machinery Laboratory. It operates on the same principle as the device developed by Culpin, but is driven by an electric motor instead of by hand; uses a hydraulic unit for recording the pressures, and the length of chart is the same as the depth of test. It is heavier in weight, but this is not a disadvantage when used at the laboratory as it is mounted on the power car. A field unit would necessarily be mounted on transport wheels. The probe is forced into the ground at approximately $\frac{1}{8}$-in per sec by the electric-motor-driven worm. A hydraulic cell is located between the guide arrangement on the lower end of the worm and the probe so that the force is transmitted through it. The pressures created are recorded on the chart to the left of the probe by means of a helical spring pen mounting. This arrangement is mounted rigidly on the probe guides so that the distance corrected for the arc of the pen arm of any point below the base line is the same as the depth of the probe. The probe consists of a $\frac{3}{8}$-in diameter rod with a $\frac{1}{2}$-in diameter head attached to the lower end. Cupped, conical, rounded, and flat heads were tried. Since there were no significant differences in the resistance to the different types, the flat head was used for all tests. Culpin[3] shows that the speed at which the probe is forced into the soil affects the resistance in a complicated relationship that may be similar to that for plows. This variable is eliminated for this study by using one speed for all tests.

In studying the data obtained with any type of unit that measures the soil condition by its resistance to penetration, a true measure of conditions is not indicated until a uniform layer of soil is encountered. Thus, if the lug equipment compacts the soil behind the lugs, then breaks this area loose to form a compacted clod, the compactness of this clod is not measured. This could probably be done only by careful apparent specific gravity determination for these

Presented before the Power and Machinery Division at the fall meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 6, 1939. The author is associate agricultural engineer, Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture.

*Superscript figures refer to literature cited at the end of this paper.

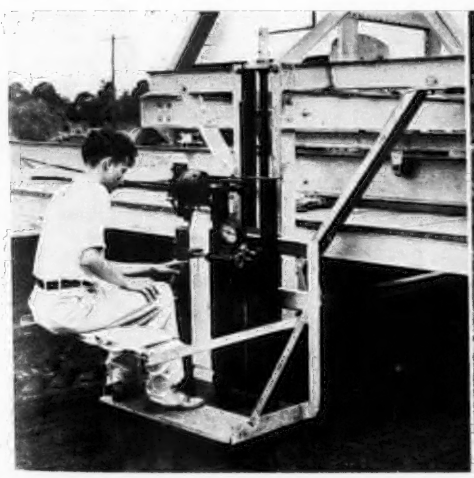
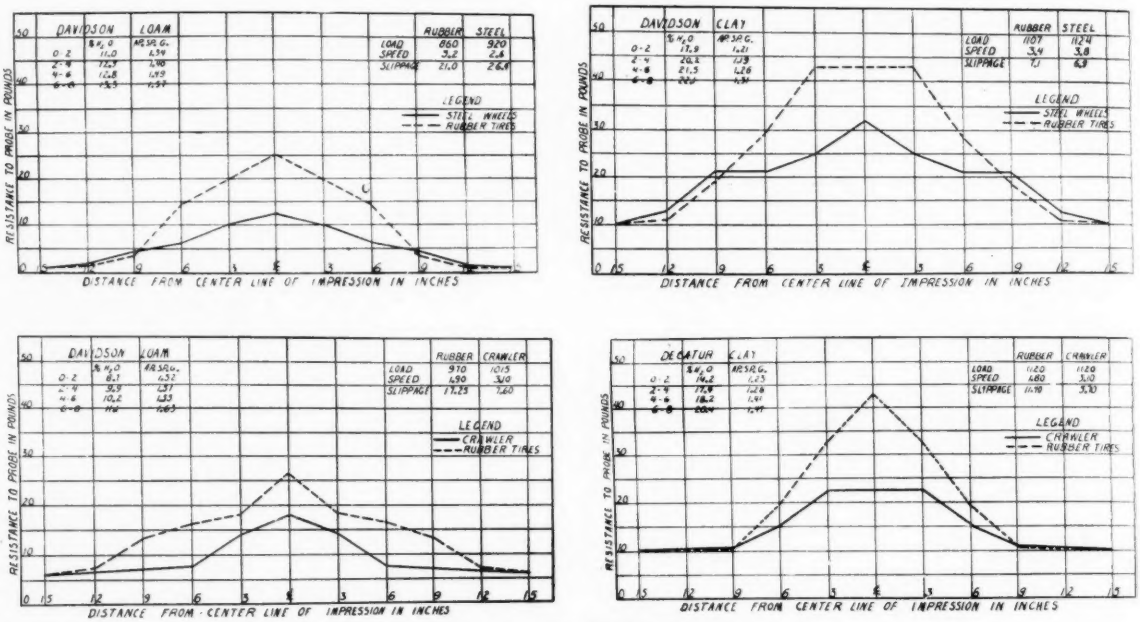


FIG. 1 (LEFT) THE POWER-DRIVEN SOIL RESISTANCE RECORDER MOUNTED ON POWER CAR. FIG. 2 (RIGHT) IMPRESSIONS PRODUCED IN DAVIDSON LOAM BY TRACKS AND BY PNEUMATIC TIRES



CURVES COMPARING PACKING EFFECTS

Fig. 3 (Upper left) Steel tires with 4-in lugs and pneumatic tires on a Davidson loam soil. Fig. 4 (Upper right) Same equipment as Fig. 3, on Davidson clay soil. Fig. 5 (Lower left) Endless tracks and pneumatic tires on Davidson loam soil. Fig. 6 (Lower right) Same equipment as Fig. 5, on Decatur clay soil

clods. The data obtained with the resistance recorder indicates the packing effects produced in the area below that loosened by the lug equipment.

The soil used for each test was prepared as uniformly as possible by subsoiling to a depth of 11 to 12 in, applying moisture if needed, compacting slightly, then leveling. The conditions used were comparable to those encountered in plowed fields, except that the soil was loosened to a greater depth. The tractor to be used was hitched to the "power car" through the dynamometer so as to tow this car for load. The desired loads were applied by using the brakes on the car. A pressure gage in the oil line between the dynamometer and recorder on the power car enabled the man operating the brakes to keep the load constant. The impressions produced in the Davidson loam by the rubber tires and tracks are shown in Fig. 2. Speeds for all tests were obtained from the dynamometer chart, and the tractor used to compare the effects of rubber tires and steel lugs was equipped with a device for recording the revolutions of the drivewheels for determining slippage. The slippage data shown in Figs. 5 and 6 were obtained from counts of the revolutions for the wheels and tracks over a measured distance. Revolutions of the wheels or tracks over the same soil conditions with no load on the tractor were used as a base.

The soil resistance recorder was located over the center of the impression made by the wheel or track and data taken by running the probe to depth of 12 to 16 in. Readings were taken on the center line of the impression and by increments of 3 in to points 15 in on either side. Duplicate readings were taken whenever possible and the data for the two sides of the impression were averaged.

Two series of tests were made. One series compares the packing of the soil, measured by resistance to a ½-in probe, produced by a general-purpose tractor equipped with steel tires and 4-in spade lugs and with 10.00x36-in pneumatic tires. Curves showing the soil resistance under the wheel impressions are shown in Figs. 3 and 4. The other series compares the packing by two tractors of approximately the same weight, one equipped with 9x24-in pneumatic tires and the other equipped with 6x50-in (ground contact measurements) tracks with 1¼-in cleats. The data for these tests are shown in Figs. 5 and 6. The soil type, drawbar loads, speed and per cent slip for each condition are shown in the figures. Table 1 shows the analysis of the three soils in which these tests were made.

The data in Figs. 3 to 6 are the resistance to the ½-in diameter probe on a plane 5 to 8 in below the surface of the undisturbed soil. The depth varied with the condition of the soil and was established for each series of tests so that it was just below the loosening effect of the deepest lug equipment. Various methods of presenting the data, including the plotting of isodensity diagrams and the averaging of the measured resistances to certain depths, were tried but the method used here appeared to give the most representative picture of what took place.

Both the steel lug and rubber tire equipment increased the resistance of the soil to penetration by the probe to the entire depth of subsoiling on the plots (12 in), whereas the effect for the track unit tapered off at 8 to 10 in for the conditions of these tests. It was noted in all tests that the rubber tires formed a more compact layer of soil immediately below the lugs than was formed under comparable conditions by either the steel *(Continued on page 285)*

TABLE 1. ANALYSIS OF SOILS

Soil	Percentage Sand	Silt	Clay	Organic matter	SiO_2/R_2O_3[a]	pH
Davidson Loam[b]	72.8	3.38	23.82	1.18	1.43	5.32
Davidson Clay	30.0	16.6	53.4	1.62	1.05	5.14
Decatur Clay	28.1	31.3	40.6	0.98	1.67	5.75

[a]Silica-Sesquioxide ratio

[b]This soil is actually a loamy sand but is referred to as loam for convenience in presentation.

Design Problems for Combined Crib and Granary

By Henry Giese
FELLOW A.S.A.E.

ALTHOUGH corn has for years been the principal crop for a group of midwestern states, the challenge of adequate construction of corn storage structures has been comparatively recent. If the "ever-normal granary" program does nothing more than teach us that corn deteriorates when not properly stored and that flimsy buildings are expensive storage facilities, it will have accomplished something well worth while. The combined crib and granary with storage space for grain over the driveway is a typical corn belt structure and commonly found in Iowa. Several advantages are offered which make it attractive to the farm operator. One particular feature is the covered driveway with inside elevator sheltering both the operator and crop while unloading. Spouts from the overhead bins make possible the removal of a large portion of the grain without hand shoveling, and corn can be shelled and elevated directly to the bins, or grain moved from one bin to another to aerate and cool it.

As they have been built, however, a number of problems have been all too often overlooked and not adequately solved. These structures need to be ruggedly built because of the large pressures involved, and because, due to the times and methods of filling, the pressures will not always be balanced as they are when both cribs and bins are full. A crib, when filled with corn, has great stability due to the almost unyielding mass it contains. In summer, when the bins are full and the cribs empty, a large weight is carried on long "stilts" often resulting in a deformed structure. The structure is also usually made more flimsy because of the necessity for leaving spaces between the siding boards to permit ventilation and aeration of the ear corn.

Presented before the Farm Structures Division at the fall meeting of the American Society of Agricultural Engineers, at Chicago, Ill., December 5, 1939. Journal Paper No. J-724 of the Iowa Agricultural Experiment Station, Project 563. The author is professor of agricultural engineering, Iowa State College.

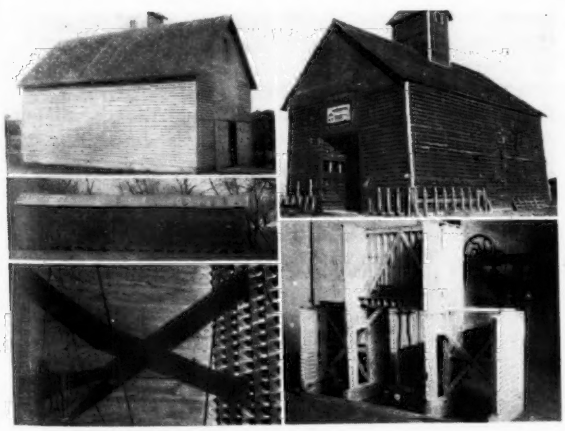


Fig. 1 (Upper left) A well-braced crib in good structural condition after 25 years of service. Fig. 2 (Center left) Lack of bracing permits a crib to become out of plumb. Fig. 3 (Lower left) X-braces in crib broken in one year's use. Fig. 4 (Upper right) Failure of joint at lower end of studs resulting from outward pressure of corn. Fig. 5 (Lower right) Test of bin partition as a support for bin floor

The first requirement of a grain storage building is that it provide the necessary conditions for maintaining the crop in good condition. As these have been adequately covered in other papers, I shall mention only that cribs must be well ventilated, including any space above the plate line, and at the same time protected against snow and rain. They should be made so that rats and mice are discouraged from entering. An additional help would be the exclusion of birds. The building should be sufficiently rugged to withstand successfully the loads imposed, without structural damage. Some such cribs have been built. Fig. 1 illustrates a substantial crib in the vicinity of Ames, built in 1915. It is now in almost its original structural condition. As will be observed, diagonal braces let into the studs under the siding assist greatly in keeping the walls plumb. The inside is literally filled with braces. Few people will go to the extent which the owner of this crib did to secure structural stability. He may have been repaid at that, because from viewing the crib in Fig. 2, we can see that the depreciation rate may be high when the only braces used are placed on the outside after the crib begins to lean. Broken interior braces, Fig. 3, constitute a troublesome problem. Repairing them may become an annual problem and sometimes they necessitate early removal of the corn and reconstruction before it is refilled. Great outward pressures at the bottom of the crib force the walls outward if not well anchored. Posts have been placed on the outside of the crib shown in Fig. 4 to prevent failure of the sidewalls.

Another problem relates to the comparative capacity required for small grain and corn. Most of the combined cribs and granaries as now built provide for more grain in proportion to the ear-corn storage than will be used on farms practicing crop rotations common in the corn belt. While many people want a wide driveway, it is my feeling that this should be as narrow as possible, consistent with the passage of a truck through it. A width of 11 feet accomplishes this and is economical in the use of 12-ft joists overhead. A wider driveway not only increases the structural problem of supporting tons of grain, but provides more grain space than most farmers can use if the crib space is adequate for the corn crop. We had one call last year for a crib with a 22-ft driveway. The prospective owner was a little put out when we suggested that he could get a much cheaper machine shed by building it as a separate structure.

One Iowa State College graduate student, J. B. Richardson, spent considerable time studying the possibilities of devising a method of framing which would place the weight of the grain in the bins upon the partitions, rather than upon the driveway walls, the expected advantage being largely in shortening the span of the joists, since the bins are usually only about 8 ft long but 11 ft wide. One of the several construction types tested by him is shown in Fig. 6. There appears, however, considerable difficulty in hanging a floor from a bin wall, while to lay it on a partition is fairly simple. The latter also distributes the weight

more uniformly, and by spacing the driveway wall studs closer provides the additional supports necessary for the diagonal siding. For this reason, the conventional framing of bin floor joists from one driveway wall to the other is still recommended.

A few years ago when working on the first edition of the Midwest Farm Building Plan Service, it appeared desirable to indicate diagonal siding on the outside. One could, without traveling far, observe numerous cribs leaning and out of shape when horizontal siding was used, and also other structures diagonally sided which remained true and plumb after many years of service. It soon developed, however, that this practice was not all gain. Many people do not like the appearance of diagonal siding. It does not shed rain quite as well as horizontal siding and tends to rot at the lower ends because the water is held there. Once the ends are decayed, repair is difficult. Some people want to side the building tight for a short distance below the cornice. Diagonal siding does not lend itself to a satisfactory joint with horizontal siding at this place. Laying the siding diagonally increases the length of span between supports. Crib siding must carry a large pressure and is placed outside the studs when for structural reasons it should be inside. If the studs are placed two feet on centers, neither the siding board nor the nail joint is adequate and the studs should be placed closer together. Diagonal siding slightly increases both the material and labor required. After considerable thought on the subject and the making of several models, it was decided to place the diagonal siding on the inside or driveway wall. Here it is just as effective as it would be on the outside. Here it does not offend in appearance, in failure to exclude rain, nor because of decay. Furthermore, since the studs on this inside wall should be closer together to take care of the added weight of the grain in the bins above, additional supports are furnished the siding, enabling both nails and siding board to hold. The increased labor or materials necessary when diagonal siding is used, is not affected when it is placed inside.

During recent years, the curved or gothic roof has become quite popular on barns and even smaller farm buildings. This roof type which as now constructed is accomplished by bending laminated beams to a large radius, effects economies in materials because of changes in direction of the wood fibers to more effectively resist the applied loads. Not only is this type of construction pleasing in exterior appearance, but it also provides interior space free from troublesome braces.

Fig. 6 illustrates a partially completed model of a curved-roof crib which it is believed offers some structural as well as functional advantages over other current types. It should be said, however, that we have endeavored to leave the selection of the roof type to the prospective owner and have felt our responsibility to end with the providing of a selection of plans orthodox in construction specified and including each.

Fig. 7 compares the arrangement and utilization of space in the gable, gambrel, and gothic roof types. The gable-roofed crib is taken from No. 73221 of the Midwest Farm Building Plan Service and the gambrel-roofed crib from No. 73222 of the same. I have single-hatched that portion available for ear corn storage and double-hatched that suitable for storing shelled corn or small grains. The open areas are not available for either.

It will be observed that there is considerable unused space in both the gable and gambrel-roofed structures. This can be reduced by walling the bins higher as shown by the dotted lines. The bins should be covered also to keep out birds, as well as husks, silks, and shelled corn which may drop from the elevator. Making the bin narrower at the top also facilitates distribution of grain in the bin and requires a shorter elevator spout.

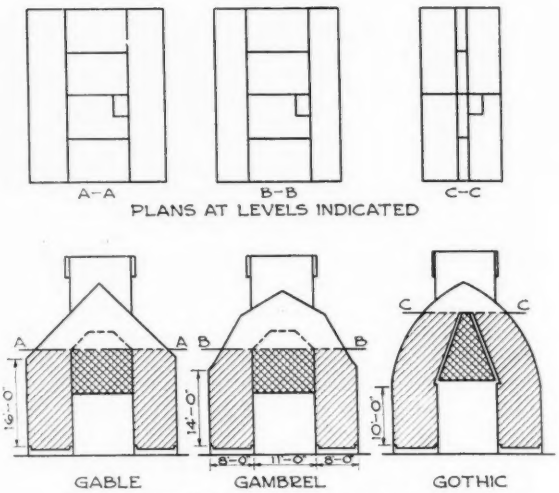


FIG. 7 COMPARISON OF CRIB AND GRANARY SECTIONS

The three buildings were designed to meet essentially the same conditions, leaving the choice of roof shape to the prospective owner. Some details are fairly well fixed by custom or by the demands of service. The angle at which an outside elevator will operate is limited and the corn will roll back down if the angle is too great. Cribs really should be designed with this in mind, since for various reasons the inside elevator may not be provided at the time of construction, or in some cases not at all. This matter becomes a problem in landlord-tenant relationship and may be a factor in the ultimate selection of crib type. A portable or outside elevator is usually provided by the tenant, while the landlord is expected to furnish an inside elevator which is fastened to and becomes a part of the building. For all practical purposes, the height of a crib is not limited by the ability of an inside elevator to raise the corn. There is a practical limit, however, due to the shattering of grain from the ear in falling. For this reason, the three cribs are essentially equal in height. From crib floor to ridge, the gable-roofed structure measures 29 ft 6 in, the gambrel-roofed one 29 ft, and the gothic-roofed one 29 ft 9 in. A comparison of the cross-sectional area and the use of space in each is given in Table 1.

TABLE 1. CROSS-SECTIONAL AREA OF CRIB AND GRANARY IN THREE ROOF PLANS

Roof type	Gross area	Cribs	Bin	Total usable	Per cent usable	Area above grain	Approx. capacity in bu per ft length Corn	Grain
Gable	621	296	88	384	62	124	118	70
Gambrel	644	291	88	379	59	138	116	70
Gothic	635	373	74	447	72	41	149	59

Note: Area figures are in square feet.

The figures in Table 1 should be considered as approximations based on preliminary designs which are subject to some change. The capacity in bushels assumes $2\frac{1}{2}$ cu ft per bushel of ear corn, with no deduction for the space occupied by structural members. Actually there will be considerable variation from year to year, due to moisture content of the corn, amount of silks, husks, etc. It is believed that the present gothic roof plan has a better ratio of ear corn capacity to small grain capacity as mentioned

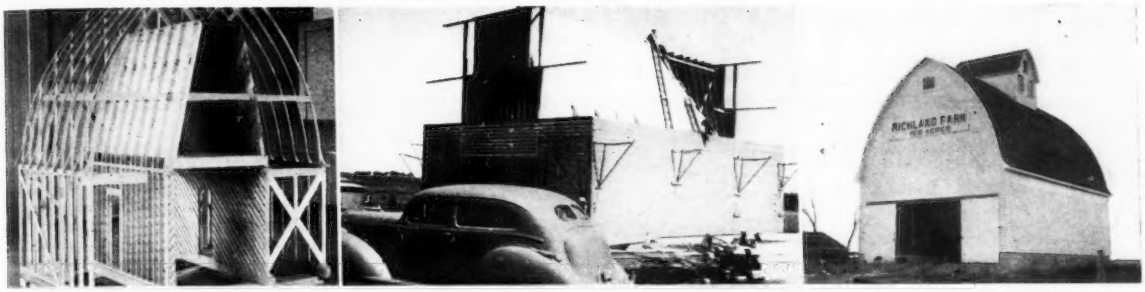


FIG. 6 (LEFT) MODEL OF CRIB AND GRANARY WITH CURVED ROOF AND SLOPING BIN WALLS. FIG. 8 (CENTER) CURVED ROOFED CRIB AND GRANARY UNDER CONSTRUCTION. FIG. 9 (RIGHT) COMPLETED CURVED ROOFED CRIB AND GRANARY

earlier. The ratios in bushels are approximately gable, 1.7 to 1.0; gambrel, 1.65 to 1.0, and gothic, 2.5 to 1.0.

This new arrangement appears to offer a number of structural advantages. The stud length may be reduced from 16 ft to 10 ft simplifying the structural problem somewhat. A 2x6-in stud 10 ft in length will carry the outward pressure of the ear corn without assistance from cross braces. A 2x2-in kick plate nailed and glued to the sill, as well as above and below the plate, gives greater bearing surface to the studs and rafters which are notched to fit it. The outward pressure against the curved roof above the plate is smaller than would be imposed upon a vertical wall, and hence is more easily retained. A dividing partition midway of the structure gives lateral stability and also may facilitate dividing the grain between landlord and tenant, especially under sealing programs now in effect. A more than usually substantial cross brace is placed on 8 ft centers.

The cover over the bins provides a convenient catwalk enabling one to easily and quickly get about in the upper portion of the structure with ready access to bins. The cribs are close together and easily filled from the centrally located elevator head. The sloping bin wall reduces the grain capacity and increases the ear corn storage, and hence makes for a better ratio of the capacity for ear corn to shelled grain. The outward pressure of the grain is also reduced; thereby cross bracing is easily provided. If crib siding is placed on the corn crib side at the bin wall studs, the space between the studs becomes an effective ventilating flue to aerate the corn above the plate. Settling of the corn after filling leaves an open space next the roof, decreases the thickness of the corn layer, and further facilitates ventilation.

Three crib sections, side by side, with ventilating spaces between, can be used instead of the driveway with overhead bins if desired.

One of the cribs as first described under construction is shown in Fig. 8. It will be noted, however, that in this case the bin wall sheathing has been placed on the outside and not on the grain side as was suggested above. The completed structure is shown in Fig. 9. The popularity of this type of construction is evidenced by the fact that one lumber dealer in Iowa has furnished the material for ten of them this year, four of which were built with sloping bin walls. If his testimony that, after twenty-five years in the lumber business, he finds farmers more interested in good construction than ever before is indicative of a trend, we have an everincreasing responsibility for providing plans which are not only functionally correct but are designed and delineated for simplicity of construction, economy and effectiveness of materials, and so easily understood that rural carpenters will erect them as specified. An "ever-normal granary" calls for permanent structures, and temporary ones are justified only as an emergency measure.

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[5]Richardson, Joe B. The structural requirements of grain storage buildings. Unpublished thesis, Iowa State College, 1938.

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A Method of Studying Soil Packing by Tractors

(Continued from page 282)

lug or track equipment. The resistance data show that the relationship between the packing effects produced by the rubber tires and tracks continued for a range of 3 or 4 in below the depth to which the lugs on the rubber tires penetrate. They show also that the packing effect as measured by the resistance to penetration for steel lug and rubber tire equipment were approximately equal for the area below the highly compacted area produced by the rubber tire. All types of traction units caused compression of the soil as much as 12 to 15 in to either side of the center line of the impression at the depths shown. These data check closely with the theoretical results expressed mathematically by Doner[4].

CONCLUSIONS

Preliminary data obtained with a power-driven soil resistance recorder indicate that all types of traction units pack the soil to a considerable depth, and that this packing effect is vectored out appreciable distances beyond the edge of the tread impression. It is indicated also that rubber tires tend to set up a more compact layer of soil than that formed by either steel lug equipment or tracks.

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[2]Heath, O. V. S. Empire Jour. Expt. Agr. 1934, part 2, page 205.

[3]Culpin, Claude. Studies of the relation between cultivation implements, soil structure, and the crop. Jour. Agr. Sci. Vol. 24, part 1 (July 1936).

[4]Doner, Ralph D. A theory of arch action in granular media. Agr. Engr., Vol. 17, No. 7 (July 1936).

NEWS

Annual Meeting Highlights

AN intensity of present and impending agricultural engineering activity, due to the war in Europe, national defense preparations, and probably other factors, gave even more than the usual businesslike tone to the thirty-third annual meeting of the American Society of Agricultural Engineers at Pennsylvania State College, June 17 to 20. Space permits only brief mention of some of the high spots.

Registration of 200 members, 48 students, 38 guests, 75 women, and 25 children accounted for a total attendance of 386.

An innovation of the meeting was its opening with technical division sessions, a general session on the afternoon of the first day, and holding of the College Division session on the closing day.

General sessions were well attended and provided inspiration and food for thought. K. J. T. Ekblaw, in his address as retiring president, made a plea to younger agricultural engineers to develop their capacities for leadership. Dr. John Lee Coulter, speaking from his viewpoint as an economist, credited much of the economic and social progress in the United States to progress in the field of agricultural engineering and resulting freedom of large numbers of people to apply their energies to matters other than the production of food.

At the second general session Dr. M. L. Wilson presented his paper, originally scheduled for the Farm Structures Division, on "The Cooperation of Industry and Government in the Advancement of Rural Housing and Farm Building."

R. W. Trullinger pictured agricultural research as a field involving many engineering problems and providing opportunity for coordination of work by agricultural engineers and various agricultural scientists.

Wheeler McMillen, in his forceful style, related agricultural engineering to farm chemurgy and national defense, particularly in connection with domestic production of important organic materials.

In the special national defense session which followed, a number of opinions were expressed, and those present indicated a desire to have the Council of the Society act as a committee on A.S.A.E. and agricultural engineers' contributions to national defense.

S. P. Lyle, as toastmaster at the annual dinner, explained "Pennsylvania prosperity," congratulated the local committee, and introduced the speakers. President Ekblaw presented the Cyrus Hall McCormick Gold Medal to Col. O. B. Zimmerman; the John Deere Gold Medal to W. W. McLaughlin; the F.E.I. trophy to the Nebraska Student Branch of the Society, represented by Dale Cox; and the duties, responsibilities, and honors of his office to the incoming president, E. E. Brackett.

Don Rose, columnist of the Philadelphia Evening Ledger, Rose-grower extraordinary, and speaker of the evening, presented with engaging good humor a simple philosophy of the importance of the unspectacular and seemingly trivial day-to-day events of ordinary decent living.

Division sessions and committee and special group meetings were held about as scheduled, and reflected interest in specific phases of agricultural engineering progress.

From the ice-cold punch with which the Pennsylvania Student Branch welcomed registrants Sunday afternoon and evening, to the friendly and complimentary formal welcome by Dr. R. D. Hetzel, president of Pennsylvania State College, the accommodations and assistance shown to individuals, and the generous program of entertainment offered for all, the local group showed a genuine and practical hospitality that kept the meeting running smoothly. Even the local weather man cooperated quite well.

Out-of-state folks found the campus a place of beauty, of new buildings, and magnificent distances. Walks between meeting places and other attractions, however, did not prevent the sessions from being well attended.

Washington News Letter

from AMERICAN ENGINEERING COUNCIL

DEFENSE PROGRAM BEGINS TO TAKE FORM

PREPAREDNESS for war continues to occupy the center of the Washington stage as the newly-appointed National Defense Commission, still in the throes of organization, begins the tremendous task of coordinating a major effort to build up the armed forces and furnish an ample supply of necessary equipment for their use. As of July 1, appropriations already approved totalled $5,362,319,748, with additional amounts still to be acted upon by Congress.

SUPERVISION OF PROGRAM

To coordinate this tremendous effort the National Defense Commission is rapidly perfecting its organization, and the federal departments concerned are steadily increasing personnel. The Commission has named a large number of advisory committees representing various sectors of industry, and has placed Donald M. Nelson, head of the Treasury's Procurement Division, in charge of coordinating all purchases.

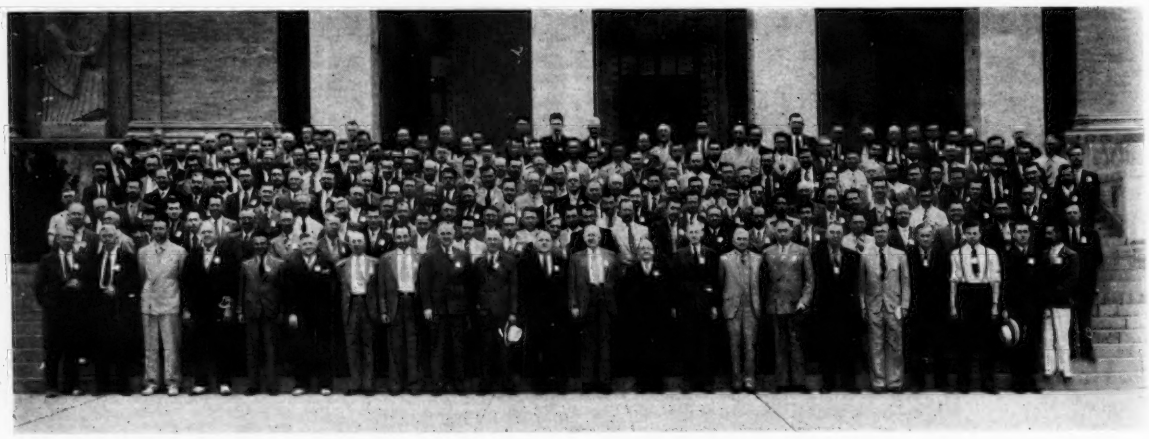
LABOR PROBLEMS

Employment in new fields for thousands of men and women naturally gives rise to many problems of adjustment that are being given careful *(Continued on page 288)*

A.S.A.E. Meetings Calendar

August 27-30—North Atlantic Section, Orono, Me.

June 23-26, 1941—Annual Meeting, Knoxville, Tenn.



A.S.A.E. MEMBERS AND GUESTS AT THE ANNUAL MEETING OF THE SOCIETY, AT STATE COLLEGE, PA., JUNE 17-20

An Appreciation of Chester Otis Reed

By Ralph A. Palmer

THE United States, particularly the State of Ohio, lost a truly great teacher and agricultural engineer in the passing of Chester Otis Reed, June 11, 1940, at Columbus, Ohio.

From a background of boyhood on a farm in upper New York State, "Chester" or "C. O." as he was affectionately called by a multitude of friends and associates, developed through a succession of agricultural and engineering studies and teaching, research, and other experience, in both public service and commercial fields, to achieve a position of recognized leadership in agricultural engineering and college teaching.

Combined with a brilliant and stimulating intellect, he had a genial, friendly, generous, enthusiastic, and cooperative nature, a dry humor, and an indomitable spirit which kept him looking ahead to the very last, in spite of repeated periods of ill health and other personal adversity.

As a teacher he rated high with college presidents and other leading educators, and with his students. For two successive years he was voted, by a large majority of representative upperclassmen, the most interesting teacher in the agricultural college of Ohio State University. He felt and lived up to a sense of responsibility to contribute to the well-rounded development as well as the technical instruction of his students. A full schedule and large responsibilities never kept him too busy to give time to helping them individually with personal problems. Many of them continued to feel, after graduation, that they were still students of his, and called on him whenever possible to renew the inspiration gained from contact with him.

Throughout his whole career he relinquished his teaching responsibilities only for a few years, during which he proved to the satisfaction of himself and others that he could also succeed in commercial administrative work. Then he returned to teaching by choice and with the conviction that it was the most important work to which he could give his life. Thereafter he refused attractive offers of administrative positions in both commercial and educational organizations in order that he might be free to continue in his chosen work of active teaching. While he taught with the apparent ease of a master of the art, he was also a keen student of the science of teaching and a leader in the development and application of progressive methods. His proficiency as a teacher also showed up in whatever extension duties came his way.

CHESTER OTIS REED

As an agricultural engineer, his specialty was field machinery, but he kept himself well-informed, maintained a broad and progressive outlook, and proved a competent adviser on all branches of agricultural engineering. His measure as an engineer showed up in his rare combination of ability to be intensely practical in matters of administration, and fundamentally scientific in questions of research.

In the A.S.A.E., Mr. Reed's membership dates back to 1909, while he was still an undergraduate. In 1912 he served as its secretary, and since that time had served almost continuously on one or more committees of the Society, including, at various times, the Council, the College Division Advisory Committee, and other standing and special committees too numerous to mention.

The Cyrus Hall McCormick Medal of the Society was awarded to Mr. Reed in 1937 for "exceptional and meritorious engineering achievement in agriculture," during a career of more than 25 years. Two of his most outstanding contributions to agriculture, in addition to his teaching, were the result of his work on European corn borer control and on fertilizer placement. Something of his character is reflected in the fact that, in accepting the award, he generously and sincerely gave much of the credit to his associates. His address as recipient of the reward was a masterful presentation of his views on agricultural engineering problems and opportunities.

The passing of Mr. Reed is the loss of a friend to all who knew him, and an abrupt end to a flow of ideas, inspiration, and accomplishments from a fertile mind and a fine character. He always saw work ahead that needed to be done, but before going to his final rest, he did much to make it easier for others to carry on. He influenced the immortal stream of humanity; but in keeping with his common touch and selfless nature it is perhaps most fitting to remember him as having been "a man among men."

BIOGRAPHICAL DATA

Chester Otis Reed was born at Gates, New York, July 26, 1885, and lived on a farm until 1904. From 1907 to 1911 he studied agriculture and engineering at the University of Illinois, graduating in the latter year with a bachelor of science degree in agriculture. He started his professional career immediately as instructor and extension specialist in field machinery at his Alma Mater. In 1917 he entered commercial work as agricultural representative of George Batten Company; became advertising manager of the Samson Tractor Company (division of General Motors Corp.); was elevated to head the company's bureau of investigation and research and made a member of its executive council in 1920; and later in the year, division sales manager. In the fall of 1922 he went to Ohio State University as assistant professor of agricultural engineering, and was raised to the rank of professor the following year. In succeeding years he also taught in various summer schools, was coorganizer of the corn borer cleanup campaign in 1926, and acted in a consulting capacity on various other projects. He married Helen Gertrude Agate in 1914 and had two children. He is survived by his widow and one daughter, Joan.

While an undergraduate he was admitted to the honorary fraternity Alpha Zeta and the professional fraternity Alpha Gamma Rho and on graduation he joined Gamma Alpha. He belonged, also, to the scientific and honor societies Sigma Xi and Gamma Sigma Delta.

LADIES PRESENT AT THE ANNUAL MEETING OF THE A.S.A.E. THEIR PROGRAM INCLUDED A FULL SCHEDULE OF SOCIAL, SIGHTSEEING, EDUCATIONAL, AND ENTERTAINMENT FEATURES

Washington News Letter

(Continued from page 286)

consideration. Engineering schools will be called upon to give short courses in drafting, surveying, and other applicable techniques.

OTHER FEATURES OF THE PROGRAM

Among the innumerable channels in which the defense effort is being exerted a few may be mentioned of particular interest to engineers:

The Treasury has been voted $47,500,000 for the acquisition of strategic materials and minerals in which shortages are apt to develop. The Reconstruction Finance Corporation, as already noted, has also been authorized to make loans for a similar purpose, and has announced its intention of immediately purchasing 150,000 tons of rubber and 75,000 tons of tin to be held in reserve.

President Roosevelt has asked for the appropriation of $25,000,000 for the installation of additional generating facilities in the Tennessee Valley Authority system.

The Commissioner of Patents has been authorized to withhold the granting, and hence the publication, of patents on devices relating to national defense.

The Census Bureau will give priority to the production statistics useful in defense in analyzing returns from the 1940 census.

Plans for the utilization of existing methods of communication for military purposes in case of war, and for the suppression of "fifth column" by radio amateurs, are being prepared by the Federal Communications Commission.

A National Defense Research Committee, headed by Dr. Vannevar Bush, president of the Carnegie Institution, has been organized "to accelerate the creation or improvement of instrumentalities for national defense." One of its problems will be the question of publishing the results of scientific investigations that might react to the advantage of a potential enemy.

Personals

C. F. Kelly is the writer of U.S.D.A. Circular No. 544, on "Methods of Ventilating Wheat in Farm Storages."

John W. Randolph, I. F. Reed, and E. D. Gordon are coauthors of "Cotton-Tillage Studies on Red Bay Sandy Loam," which is published as Circular No. 540 of the U. S. Department of Agriculture.

H. P. Smith was awarded his professional degree in agricultural engineering at the spring commencement exercises of the Texas A. and M. College. A column-length story of his training, experience, and professional activities was published in the Byran (Texas) Daily Eagle of June 1.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the June issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

S. J. Baldwin, 5704 Hudson St., Dallas, Tex.

Clarence J. Bergschneider, student trainee, International Harvester Co. (Mail) Center, Mo.

Dan B. Billington, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 1085, Elkins, W. Va.

L. B. Bryan, camp agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) 619 S. Elm St., Ottawa, Kans.

Wallace J. Campbell, Rising Fawn, Ga.

W. E. Carroon, assistant agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) 221 S. Miranda St., Las Cruces, N. M.

R. Barry Cecil, retail and service, J. W. Darden & Son. (Mail) Gallatin, Tenn.

George A. Crabb, Jr., assistant engineering aide, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Spartanburg, S. C.

George W. Crowther, extension instructor, agricultural engineering department, Cornell University, Ithaca, N. Y. (Mail) 209 College Ave.

John F. Cykler, repair man, Minneapolis-Moline Power Implement Co. (Mail) 3160 California St., Huntington Park, Calif.

Wendell C. Dean, sales promotion, Aermotor Co., Chicago, Ill. (Mail) 1344 Argyle Ave.

Paul C. Dillon, International Harvester Co. (Mail) 126 Groveland Pl., San Antonio, Tex.

Henry L. Espensen, West Branch, Iowa.

James L. Gattis, Pottsboro, Tex.

Roy W. Godley, agricultural counsellor, Monongahela West Penn Public Service Co., Bethlehem Bldg., Fairmont, W. Va.

Glenn W. Grubb, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 132, Ripley, W. Va.

R. L. Hearon, Bishopville, S. C.

Clyde H. Emmons, Box 5397, College Station, Tex.

Roger C. Johnson, patent lawyer, Deere & Co., Moline, Ill. (Mail) Box 272.

Walter H. Kendall, sales representative, Frick Co. (Mail) Shelburne, Vt.

Leo W. Larsen, Coleman, S. D.

C. Blaine Lytle, rural supervisor, Monongahela West Penn Public Service Co. (Mail) Parkersburg, W. Va.

W. L. MacArthur, automotive engineer, Standard Oil Co. (Mail) 836 W. Macon St., Decatur, Ill.

James E. McCay, Box 53, Ila, Ga.

William E. McCune, J. I. Case Co. (Mail) 3422 Wabash, Kansas City, Mo.

Bruce McDonald, 112 S. 5th St., Moberly, Mo.

Melvin C. Miller, junior agricultural engineer, Soil Conservation Service, U. S. Department of Agriculture. (Mail) Box 425, Lewisburg, W. Va.

John B. Mitchell, 85 St. Dunstans Rd., Asheville, N. C.

Erling J. Nossum, Milnor, N. D.

W. H. Parady, utilization specialist, Rural Electrification Administration, U. S. Department of Agriculture. (Mail) Monroe, Ga.

Robert A. Parmele, experimental department, Dain Manufacturing Co., Ottumwa, Iowa. (Mail) 117 E. Court St.

Richard L. Patrick, engineer trainee, Rural Electrification Administration, U. S. Department of Agriculture, Washington, D. C.

T. L. Reeves, assistant county agent, Greensboro, N. C. (Mail) 403 W. Sycamore St.

Glenn E. Saha, assistant agricultural engineer, Iowa State College, Ames, Iowa. (Mail) 405 Hayward St.

Edwin I. Shanfeld, Pulliam Bros. Terrace Contracting Co. (Mail) 7412 Buckingham St., St. Louis, Mo.

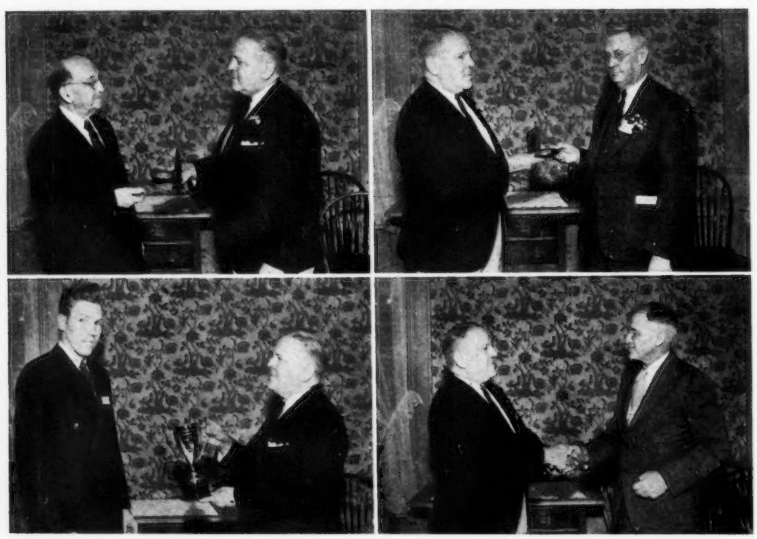
William E. Skelton, RR No. 2, Blackstone, Va.

R. M. Tarbell, power machinery manager, John Deere Plow Co. (Mail) 125 Marcellus St., Syracuse, N. Y.

Nelson W. Taylor, state community services specialist, Farm Security Administration, U. S. Department of Agriculture. (Mail) Box 678, Morgantown, W. Va.

Thomas H. Weeks, Chamberlain, S. D.

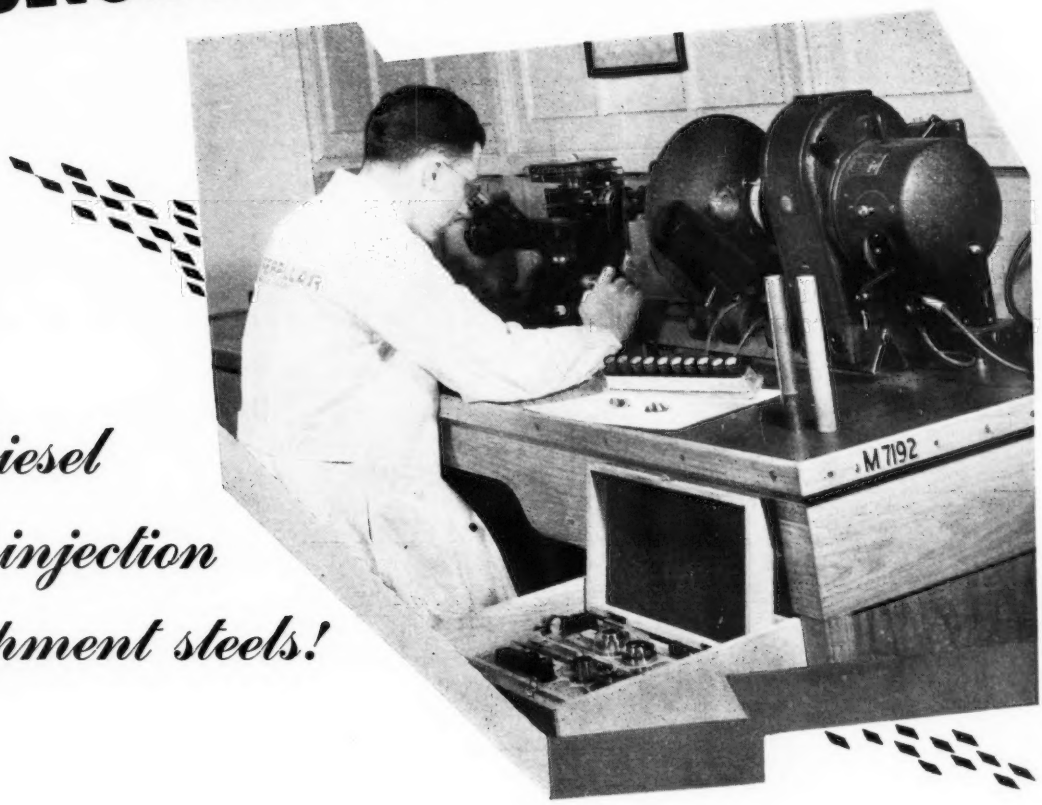
Homer D. Witzel, agricultural engineer, Gehl Bros. Mfg. Co., West Bend, Wis. (Mail) 201 N. Randall.



DOING THE HONORS AT THE ANNUAL DINNER

(Upper left) President Ekblaw presents the Cyrus Hall McCormick Gold Medal to Col. O. B. Zimmerman. (Upper right) Presenting the John Deere Gold Medal to Walter W. McLaughlin. (Lower left) The F.E.I. Trophy being presented to Dale Cox, representative of the Nebraska Student Branch. (Lower right) President Ekblaw congratulates and turns over his office to E. E. Brackett

MICROSCOPIC CLEANLINESS



of Diesel fuel injection equipment steels!

UNDER 1,500 times magnification, an object 10 inches high would appear almost as tall as the Empire State Building. The *Metallographical Microscope*, shown in use here, is capable of this degree of resolving power. (The dictionary says resolving power is "the ability of an optical instrument to form distinguishable images of objects separated by small angular distances.")

The operator is looking for inclusions, "dirt," in alloy steel to be used for making "Caterpillar" Diesel fuel injection equipment. Magnification: 100 times.

Specimen bars, standing on end upon the table, have been taper ground and etched, for re-examination—to determine if any inclusion or "dirt" has elongated in rolling. Steel has to have high cleanliness and freedom from any harmful inclusions to be approved for use in "Caterpillar" Diesel fuel injection equipment. For the precision fit of a fuel pump plunger results from holding the limit of tolerance within plus or minus twenty-five millionths (0.000025) of an inch! Leadership is "Caterpillar's" reward for such precision!

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DIESEL ENGINES TRACK-TYPE TRACTORS TERRACERS

Agricultural Engineering Digest

A review of current literature by R. W. TRULLINGER, assistant chief, Office of Experiment Stations, U. S. Department of Agriculture. Copies of publications reviewed may be procured only from the publishers thereof, whose names and addresses may be obtained on request to AGRICULTURAL ENGINEERING, St. Joseph, Michigan

LIFE, SERVICE, AND COST OF SERVICE OF PNEUMATIC TRACTOR TIRES, *E. G. McKibben and J. B. Davidson.* Iowa Sta. Bul. 382 (1939), pp. 165-186, figs. 5. Cooperators using a total of 199 sets of pneumatic tractor tires reported reduced fuel and labor requirements; higher speeds; easier operation on hard surface roads; less damage to farm roads, lanes, meadows, and pastures; decreased tractor breakage and wear; and greater comfort. These users were located in 73 counties and represent the equivalent of 381 years of individual observation.

The use per year reported ranged from 240 to 3,000 hr, with an average of 984 hr. Hauling constituted, on the average, about 4 per cent of the use of rubber-tired tractors, varying from 0 to 75 per cent, with an apparent tendency to increase. Considerable variation in the rate of tire wear was reported, and the necessity of avoiding excessive slippage was frequently emphasized. Annual maintenance costs were found to average 28 cents per set per year, although in individual cases annual costs averaged as high as $5. The estimated useful life varied from 3 to 15 yr, with an average of 7 yr, and the estimated useful hours of use averaged 6,765. Estimated fuel savings for the same work ranged from 0 to 50 per cent, average 22 per cent. An average labor saving of 23 per cent was reported, with the range from 5 to 50 per cent. The use of a higher gear for most field operations was reported by 54 per cent, and 93 per cent used a higher gear for at least one important implement. The use of machines of greater operating width was reported by 40 per cent. High lug treads were reported as being generally more satisfactory, particularly for adverse traction conditions. All but 3 of the 40 users who had tried water as a substitute for cast iron wheel weights were satisfied with the plan.

Disadvantages reported were higher first cost, possibility of delay and expense from accidental damage, expense of equipping at least part of the drawn equipment with rubber tires, lower maximum drawbar pull under many conditions, excessive bouncing under certain conditions, more objectionable tracks in loose tilled soil, and decreased stability for belt work. Over 98 per cent of the users, however, were satisfied with the performance of pneumatic tractor tires.

The authors note that the most effective use of a rubber-tired tractor requires the highest practicable speed, the widest implement which can be pulled satisfactorily by the engine and tires at this speed, and enough wheel weight to provide effective traction.

EROSION LOSSES FROM A 3-DAY CALIFORNIA STORM, *J. G. Bamesberger.* U. S. Dept. Agr., Soil Conserv. Serv. (1939), pp. 23, figs. 32. The extent of erosion was measured, and the type of treatment of the land, the kind and condition of cover, slope, soil type, condition of soil, and previous conditions of erosion were recorded. Measurements of the size of new gullies, erosion in the old gullies, the area covered by deposits, the depth of the overwash, and the extent of landslips were also made. The number of new gullies and landslips was recorded. The report contains measurements on gullies and deposition in the Las Posas project area and observations of landslips, particularly in the La Habra area. A pictorial section follows the report.

SMALL RESERVOIRS FOR STOCK WATER AND IRRIGATION, *O. W. Monson.* Montana Sta. Cir. 154 (1939), pp. 33 + [1], figs. 16. The need for artificially made stock-water reservoirs arises from the often excessive distances between natural watering places, and the need of artificial reservoirs for irrigation purposes comes of the character of the natural runoff of the State, which is such that excessive flows of water, reaching flood stages, occur frequently during May and June, followed by drying up of streams to such a degree as to cause serious water shortage in July and August. Differences, often reaching 400 per cent, in the runoff from the same watersheds in two consecutive years add to the urgency of the problem, of which a suggested solution is control of all streams by constructing dams and reservoirs which will store the runoff for stock water and irrigation.

This circular deals with the location, design, and construction of small earth dams and the costs of such works and contains supplementary information concerning the measurement of the capacity of a reservoir (appendix A), the staking out of a small earth dam (appendix B), and the calculation of the runoff from watersheds of various sizes (appendix C).

This circular is a revision of Bulletin 301.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE SOUTH DAKOTA STATION, South Dakota Sta. Rpt. 1939, pp. 41, 49-51, fig. 1. This report contains notes on experiments with the rammed earth construction for a brooder house for chicks, by W. E. Poley and R. L. Patty; rammed earth walls, with and without protective covering with plaster panels, for farm biuldings, by Patty, H. M. Crothers, and H. H. DeLong; comparison of galvanized with painted steel fence posts, by Patty; use of rubber tires on farm vehicles, by DeLong; and hitches for tractors and large horse teams, by D. E. Wiant, Patty, and DeLong.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE ILLINOIS STATION. (PARTLY COOP. U.S.D.A. ET AL.) Illinois Sta. Rpt. 1937, pp. 236-262, figs. 5. The following captions indicate the scope of this work: Studies indicate rural use of electric power, by E. W. Lehmann and A. L. Young; weather influences proper operation of septic tanks, by Lehmann and A. M. Buswell; light oils give better lubrication in gasoline tractors and rubber tires and high compression prove success on tractor, both by R. I. Shawl; cost reduction factor is studied in drainage maintenance, by J. G. Sutton, H. D. Fritz, and Lehmann; terraces easily made and worth more than their cost, by Lehmann and R. C. Hay; small combines have relatively more threshing capacity, by Young, P. Bateman, and W. M. Hurst; best power and machines for soybean production studied, by H. P. Bateman and Lehmann; seed corn vitality increased by drying procedures, by Lehmann, R. H. Reed, W. L. Burlison, and G. H. Dungan; underground pipes may improve stationary spraying plant, by Lehmann, Reed, H. W. Anderson, and R. L. McMunn; some pipes withstand apple-washing solutions, by Reed; fuel gas from ground soybeans not feasible, by H. P. Rusk, Buswell, Lehmann, E. E. DeTurk, and L. J. Norton; several new plans for farm buildings are now available, by W. A. Foster; four conclusions reached on grain storage problems, by W. Ashby, T. Cleaver, and Foster; and improved seed cleaning sought as aid in weed control, by Lehmann, C. W. Veach, and L. V. Sherwood.

THE GLUED LAMINATED WOODEN ARCH, *T. R. C. Wilson.* (Coop. Univ. Wis.) U. S. Dept. Agr., Tech. Bul. 691 (1939), pp. 123, figs. 73. Wood has the necessary tensile and compressive strength and bending resistance, but its use in arches has been retarded because ribs of the necessary size and curvature can be formed only by assembling pieces sawed to shape or by superimposing bent layers or laminae. In the first type the assembly is weakened by the necessary joints and by nonparallelism of wood fibers to the axis; in the second, available mechanical connections such as nails, screws, bolts, or dowels permit sliding of one lamina on another, and the assembly of laminations does not act as a unit. Efficient laminated wooden arch ribs and other members are now made available, however, through the use of glues of proven durability to bond laminae together as a unit so that resistance to sliding or shear is as great between the layers as within the wood itself.

This bulletin discusses recent research on the strength of glued laminated construction conducted at the Forest Products Laboratory and presents recommendations for specifications and design stresses, together with other information for engineers, architects, and builders. Much of the information applies to other structural members, such as straight, cambered, or curved beams and curved chords for trusses, as well as to arches. Framework arches are not considered, however.

In all curved glued laminated structural members considered in this bulletin thickness of laminations is so adjusted to the curvature that steaming or other softening treatment as used in bending wood for other purposes is not required, and bending and gluing are done in one operation. Straight glued laminal structural members are also taken up. *(Continued on page 292)*

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Agricultural Engineering Digest

(Continued from page 290)

REPORT OF THE CHIEF OF THE BUREAU OF AGRICULTURAL CHEMISTRY AND ENGINEERING, 1939, *H. G. Knight.* U. S. Dept. Agr., Bur. Agr. Chem. and Engin. Rpt. 1939, pp. 98. This first report of the newly constituted Bureau includes food research on vegetables and vegetable processing, citrus, apple, and other fruit products, the baking and staling of bread, rancidity of vegetable oils, composition of wildrice, eggs and egg products, enzymes, composition and properties of naturally occurring fat acid glycerides, flavor of Montmorency cherry juice, physiological investigations of phenothiazine and other insecticides, chronic toxicity of cadmium, chemistry of tobacco mosaic virus, the preservation of biological specimens, and the removal of hulls from sticktight walnuts; carbohydrate research with sugarcane and cane sugar, beet sugar, farm-made sirups, honey, starch extraction from sweetpotatoes, and hemicelluloses; oil, fat, and wax investigations with stillingia oil, ben or moringa oil, and the deterioration of tung nuts in storage; protein research on the digestion of casein with trypsin and the consequent liberation of cystine, zein and other proteins in corn, effects of storage on proteins of grains and seeds, selenium in toxic plants, and effects of raw soybean meal on vitamin A; allergen investigations with cottonseed and cotton products; hides and skins, tanning materials, and leather; bagasse molding powders; lignin, hemicelluloses, and lignocelluloses; fermentation investigations with *Rhizopus oryzae, Aspergillus niger,* and *Acetobacter;* chemical conversion of oils, fats, and waxes; preparation of plastics; utilization of soybeans and soybean products; production and use of sodium chlorate; naval-stores research; fertilizer research; and engineering research.

ENGINEERING MANUAL.—SECT. I, JOB PLANNING AND ESTIMATING IN LAND DEVELOPMENT, *T. B. Chambers.* U. S. Dept. Agr., Soil Conserv. Serv. 1939, SCS-EP-16, pp. 39. This manual contains instructions, methods, and data for planning and organizing construction on Soil Conservation Service and land-use development projects and for estimating costs, most of the data applying to such works as buildings, dams, roads, bridges, water supply, and sanitary systems. These data have been prepared primarily to facilitate job planning but "may also be valuable reference material for the preliminary estimating required in connection with preparing initial project development plans and current work programs or revisions thereof."

RUBBER-TYRED FARM VEHICLES, *W. S. Lockwood.* Brit. Rubber Pub. Assoc., Rubber and Agr. Ser. Bul. 12 (1939), pp. [1] + 12, figs. 6. The claim is made that normally one horse, mule, or other animal can readily pull on low-pressure tires what would require a team on steel. Some other advantages noted are that ground which cannot be traversed with iron-wheeled wagons is easily crossed on rubber tires; that larger loads can be carried smoothly and speedily, with particular advantage in the handling of perishable products, livestock, etc.; that wheel maintenance charges are reduced, and the wagon itself is protected from the bad effect of jolts and jars; that the ground and grass or other cover crops are not damaged by ruts; that such equipment provides much greater comfort for the driver; that new and improved designs of wagons of lighter construction and larger capacity, incorporating a lower loading line, are practicable; and that the farm wagon can be readily converted to a tractor trailer.

RAINFALL AND DISCHARGE RECORDS FOR NORTHERN IOWA DRAINAGE DISTRICTS, *W. J. Schlick.* Iowa Engin. Expt. Sta. Bul. 141 (1939), pp. 72, figs. 44. This study of rainfall and drainage discharge was undertaken (1) to determine the rates of runoff for which drainage districts in northern Iowa should be designed and (2) to study the changes which extensions of farm-lateral systems produce in the discharge characteristics of such districts. The field data include rainfall and discharge records for each season, April to October inclusive, in the 13-yr period, 1920-32, for three districts with drainage areas of 12, 25, and 35 sq mi (including two tile-lateral areas of 4.5 and 1.25 sq mi), the dredged channel for the west fork of the Des Moines River with a drainage area of 2,190 sq mi, and a tile district of 3.5 sq mi without surface inlets. Frequency studies of rainfalls and of peak rates of runoff by the station-year method were also carried out, and the results were used as a basis for evaluating the discharge data.

The extensions of farm-lateral systems were found not sufficient to permit conclusions concerning their effects upon the discharges from the various districts. The data contribute to the information concerning the probable magnitudes and frequencies of maximum rainfalls and discharges from drainage districts and the frequencies, volumes, and durations of excesses in discharge above selected design rates of runoff.

THE THERMAL CONDUCTIVITY OF DRY SOILS OF CERTAIN OF THE GREAT SOIL GROUPS, *W. O. Smith and H. G. Byers.* (U.S.D.A.) Soil Sci. Soc. Amer. Proc., 3 (1938), pp. 13-19, figs. 3. The authors describe an apparatus for determining the thermal conductivity, k, in the equation $k = \frac{Q/At}{T_2 - T_1/d}$, of a soil sample held in the form of a slab of uniform thickness (d) and exactly determined area (A) between cold plates of controlled temperature (T_1) and a heated plate of which the temperature (T_2) and energy supply can be measured accurately, so that the quantity of heat (Q) passing during a determined time interval (t) may be calculated. A diagrammatic drawing and photograph indicate the general nature of the setup. Data for a number of soils are given, and, although it is pointed out that "exact mathematical treatment of the problem of heat transmission in a porous body is difficult," an approximate relation is derived.

CROPS AGAINST THE WIND ON THE SOUTHERN GREAT PLAINS, *G. K. Rule.* U. S. Dept. Agr., Farmers' Bul. 1833 (1939), pp. [4] + 74, figs. 44. The agricultural history of the Great Plains area is outlined, with special reference to the factors, such as overgrazing, improper tillage methods, inadequate moisture conservation, and the plowing up of soils climatically or otherwise ill-adapted to cultivated crops, which have contributed most importantly to the development of wind-erosion and duststorm hazards. The usually recommended present methods of soil and moisture conservation are discussed, together with the tillage implements best adapted to the work. Both crop management and range management are taken up.

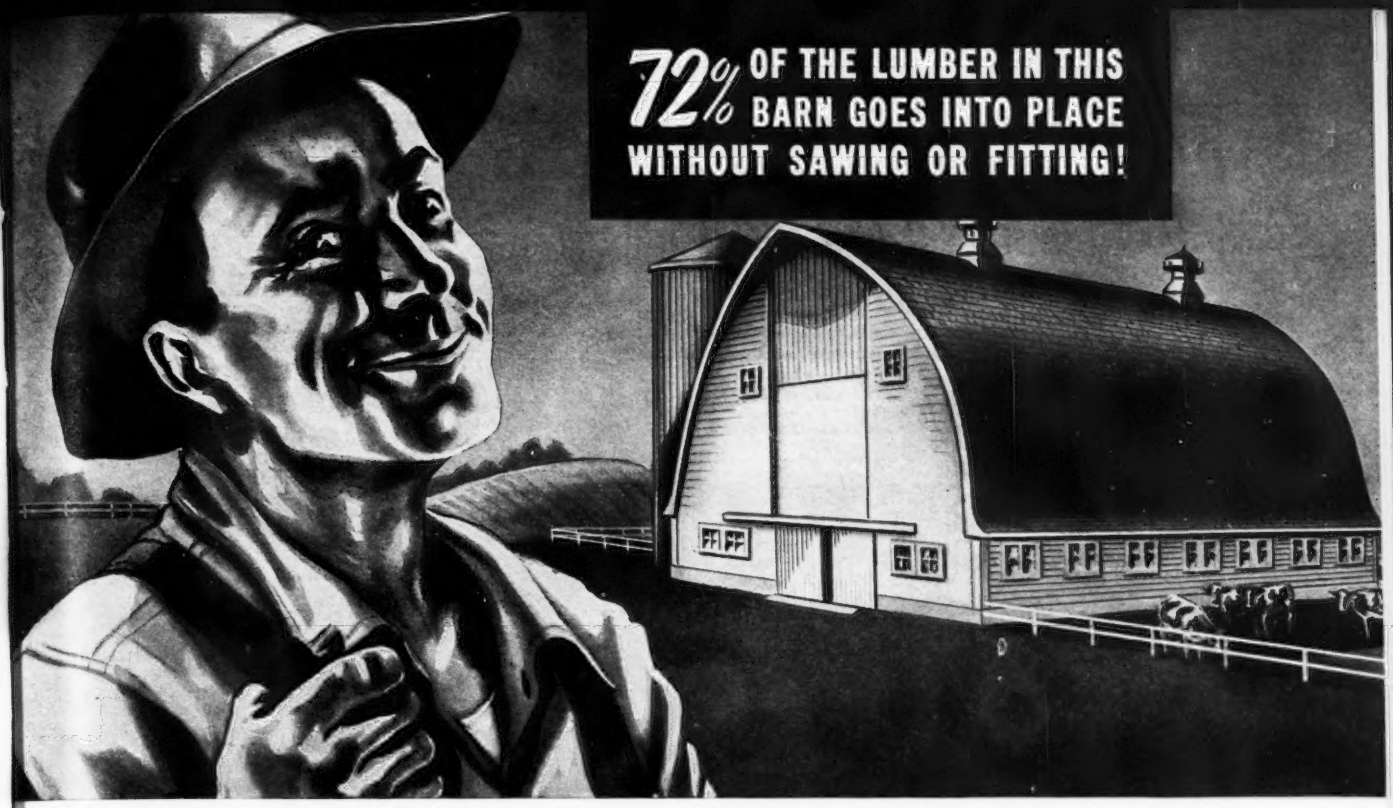
LAND DRAINAGE AND RECLAMATION, *Q. C. Ayres and D. Scoates.* New York and London: McGraw-Hill Book Co., 1939, 2. ed., pp. XI + 496, figs. 316. This is a revision of a work previously noted. The introduction has been entirely rewritten, the chapter on land clearing has been shortened, that on erosion control has been expanded into three chapters, and minor additions of new material and illustrations have been made throughout the book, including a discussion of soil-conservation districts added to the chapter on drainage districts.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE WASHINGTON STATION. (Partly coop. U. S. D. A. et al.) Washington Sta. Bul. 384 (1939), pp. 11, 12, 80, 81. The use of electricity in Washington agriculture is reported upon by L. J. Smith and H. L. Garver, and cold-storage investigations (including studies of the community locker type cold-storage plants) are also noted by Smith. Time of irrigation and the quantity of water used, and methods of irrigation are briefly discussed by H. G. Nickle.

SOIL INVESTIGATIONS AT THE WASHINGTON STATION, (Partly coop. U. S. D. A. et al.) Washington Sta. Bul. 384 (1939), pp. 17-22, 86-92. Notes on fertility investigations of Washington soils are contributed by L. C. Wheeting, S. C. Vandecaveye, and L. E. Dunn; the maintenance of organic matter in eastern Washington soils, by Vandecaveye, Wheeting, and L. T. Kardos; plant composition as influenced by fertilizers and soil type, by Vandecaveye and Dunn; fertility investigations of greenhouse soils, by Wheeting and Dunn; the effect of various cropping systems in the Palouse region upon the leaching through the soil of plant nutrients and other chemical constituents, by Kardos and Vandecaveye; changes occurring in irrigated soils in the Wenatchee and Yakima Valleys as a result of irrigation and fertilizer treatments, by Vandecaveye and Wheeting; land classification and soil surveys, by Wheeting; utilization of fertilizers on representative upland soils in western Washington, by Wheeting, Vandecaveye, and Dunn; investigations of the accumulations of arsenical sprays in orchard soils, by Kardos, Vandecaveye, and E. A. Epps; fertility of irrigated soils, by Vandecaveye, Wheeting, and H. P. Singleton; and legume culture distribution, by Vandecaveye.

Studies in soil erodibility, effect of plant cover on runoff and erosion, and relation of cropping practices to erosion control are all noted by G. M. Horner; and tillage practices for erosion control, and runoff from agricultural watersheds, both by Horner and L. M. Naffziger. Observational nursery for herbaceous species and for woody species are discussed by J. L. Schwendiman and A. J. Johnson and by P. E. Lemmon, R. L. Brown, W. E. Chapin, and H. W. Miller, respectively; observational field plantings of herbaceous species, by R. F. Sackman and Johnson, and of woody species, by Lemmon, Brown, Chapin, and Miller; seed increase of foundation stock, by Johnson and Sackman; production of nursery stock, by Lemmon, B. L. Peters, Brown, and Johnson; outlying nurseries, by V. B. Hawk; seed and plant collection and distribution, by L. A. Mullen; and seed analysis, by D. D. Forsyth and Mullen.

(Continued on page 294)



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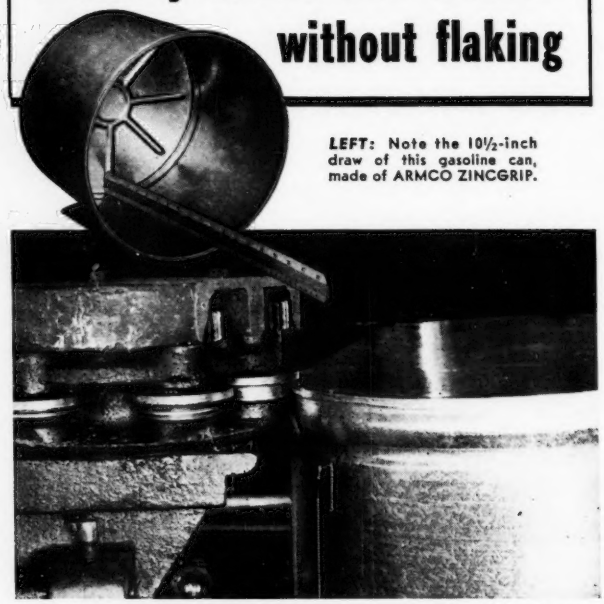

LEFT: Note the 10½-inch draw of this gasoline can, made of ARMCO ZINCGRIP.

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Agricultural Engineering Digest

(Continued from page 292)

HYDROLOGIC STUDIES: COMPILATION OF RAINFALL AND RUNOFF FROM THE WATERSHEDS OF THE NORTH APPALACHIAN CONSERVATION EXPERIMENT STATION, ZANESVILLE, OHIO, 1933-38, *H. L. Borst and R. Woodburn.* U. S. Dept. Agr., Soil Conserv. Serv. 1939, SCS-TP-26, pp. [3] + 25 + [136], figs. 115. The station tract consists of approximately 250 acres on the upper reaches of Timber Run, a small tributary of the Licking River, which joins the Muskingum at Zanesville. The station is located about 8 miles northwest of Zanesville, Muskingum County. It is hilly, ranging in elevation from about 880 to 1,040 ft above sea level. The soil is chiefly Muskingum silt loam. Associated types are Wellston and Eifort silt loams. The effects of land use on runoff and erosion were studied on a pasture watershed of 3.57 acres, a cultivated watershed of 2.55 acres, and a wooded watershed of 2.23 acres. All storms are tabulated, and about 10 or 12 important runoff producing storms each year are analyzed in detail. Data concerning the instruments used (rain gages, Parshall flumes, and Ramser silt samplers) are given in tabular form, and methods used in compiling rainfall and surface runoff data are briefly discussed. Appendix A, by N. L. Eriksson, consists of a description of the wooded watershed, appendix B is made up of maps, and the recorded data constitute appendix C.

LIST OF PUBLICATIONS ON CHEMISTRY OF WOOD AND DERIVED PRODUCTS, JULY 1939. (Coop. Univ. Wis.) U. S. Dept. Agr., Forest Serv., Forest Prod. Lab. 1939, pp. [1] + 33. This bibliography contains instructions for obtaining publications, a general reference list, and classified references under the following captions: Chemical composition of wood, chemical and physical properties of wood, chemical industries using wood, chemistry of wood preservatives, and other publication lists issued by the Forest Products Laboratory, the first three classifications being further subdivided into several more specific topics.

COTTON GINNING EQUIPMENT AND PRACTICES IN TENNESSEE, *C. E. Allred and B. D. Raskopf.* (Coop. U. S. D. A.) Tennessee Sta., Agr. Econ. and Rural Sociol. Dept. Monog. 101 (1940), pp. [1] + IV + 34, figs. 7. The number of ginneries, by years from 1902 to 1939, and their ownership and management are given, and ginneries are classified by power used, by size and capacity, and by such specified equipment as fans, seed-cotton driers, cleaners and extractors, distributors, type of gin, lint flues and condensers, and trampers, presses, and press boxes. Other topics taken up include preparation of cotton ginned in Tennessee, charges for ginning, improvements in ginning in Tennessee, and ginneries reported active in Tennessee, 1939. A bibliography is added, together with a list of the monographs in this series.

A HOMEMADE EGG-COOLER FOR FARM USE, *R. B. Thompson and C. A. Roberts.* Oklahoma Sta. Bul. 240 (1940), pp. 16, figs. 7. The device described is a summer egg cooler, using the evaporation of water to reduce the temperature and designed to be of value only through the hot, dry summer months. Because the cooler also provides moisture, it prevents the eggs from going stale due to evaporation of their contents when exposed to hot, dry weather. The device consists of an open framework of 1x4-in slats covered with burlap, with provision for keeping the burlap saturated with water. The outside dimensions of the framework should be 36 in wide, 36 in high, and 33.75 in deep to hold two egg cases and provide an adequate amount of space for a precooling tray and wire basket. It was found that burlap, with its more open weave, permitted a greater circulation of air than did other covering materials, a provision which was necessary to prevent mold from developing on the eggs.

Experimental work with the summer evaporation cooler showed that eggs held longer than 7 days are likely to develop a damaging mold growth. Eggs held at high and dry temperatures before storage were found to lose quality rapidly while in storage. Eggs held in the summer evaporation egg cooler before storage had much better quality after storage than eggs held in a normal temperature room.

AGRICULTURAL ENGINEERING INVESTIGATIONS AT THE MISSOURI STATION, Missouri Sta. Bul. 413 (1940), pp. 13-15, fig. 1. Work on size, depth, and spacing of tile drains for Missouri soils is reported upon by J. C. Wooley; electric brooding of chicks and operating costs of electric fence controllers, both by M. M. Jones and W. A. Junnila; contour furrowing for pastures (this work including the design of a furrowing machine to build furrows without losing sod or exposing subsoil and a draft sufficiently low so that an ordinary farm tractor may be used for power), by Wooley, Jones, and X. McNeal; seedbed preparation studies, by Jones and McNeal; and the effect of environment on laying hens, by Wooley and E. M. Funk. *(Continued on page 296)*

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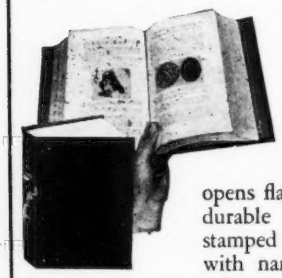

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Agricultural Engineering Digest

(Continued from page 294)

FARM FENCES, *M. A. R. Kelley*. U. S. Dept. Agr., Farmers' Bul. 1832 (1940), pp. [2] + 58, figs. 64. This publication presents a more or less popular discussion of rail, board, stone, barbed-wire, and woven-wire fences. The advantages and disadvantages of electric fences are stated nontechnically, with the warning that the safety factors have not been thoroughly worked out and standardized. Posts of wood, metal, and concrete and their spacing are taken up, together with life of fences, cost of fencing, construction methods, lightning protection, gates and entrances, and maintenance of fences.

Literature Received

COMPILATION OF RAINFALL AND RUN-OFF FROM THE WATERSHEDS OF THE NORTH APPALACHIAN CONSERVATION EXPERIMENT STATION, ZANESVILLE, OHIO (1933-38), by H. L. Borst and Russell Woodburn. Paper bound, Mimeographed, 8x10½ in. A compilation of data recorded, presented largely in tables and graphs, with brief descriptive information on the station, watersheds, instrumentation, and methods of compiling the data. One of a series of publications on Hydrologic Studies. SCS-TP-26 (August 1939).

COMPILATION OF RAINFALL AND RUN-OFF FROM THE WATERSHEDS OF THE MISSOURI VALLEY LOESS REGION CONSERVATION EXPERIMENT STATION, CLARINDA, IOWA (1934-38), by L. H. Schoenleber. A publication similar to the above, and one of the same series on Hydrologic Studies. SCS-TP-31 (May 1940).

EMPLOYMENT BULLETIN

The American Society of Agricultural Engineers conducts an employment service especially for the benefit of its members. Only Society members in good standing may insert notices under "Positions Wanted," or apply for positions under "Positions Open." Both non-members and members seeking to fill positions, for which ASAE members are qualified, are privileged to insert notices under "Positions Open," and to be referred to members listed under "Positions Wanted." Any notice in this bulletin will be inserted once and will thereafter be discontinued, unless additional insertions are requested. There is no charge for notices published in this bulletin. Requests for insertions should be addressed to ASAE, St. Joseph, Michigan.

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POSITIONS WANTED

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AGRICULTURAL ENGINEER with B.S. degree from southern college and M.A. degree from midwestern university (1938), desires employment as instructor, with farm implement company, or in agricultural extension. Has five years' teaching experience, one year research, and two years as construction supervisor. Farm background. Age 33. Married. Reference and professional record available upon request. PW-322

AGRICULTURAL IMPLEMENT ENGINEER, graduate of A. & M. College of Texas in 1929, desires employment in the agricultural implement field, preferably something in the nature of a designing foremanship. Has had several years of design experience in most agricultural lines, except tractors and tractor equipment, and is well acquainted with shop practice. PW-323